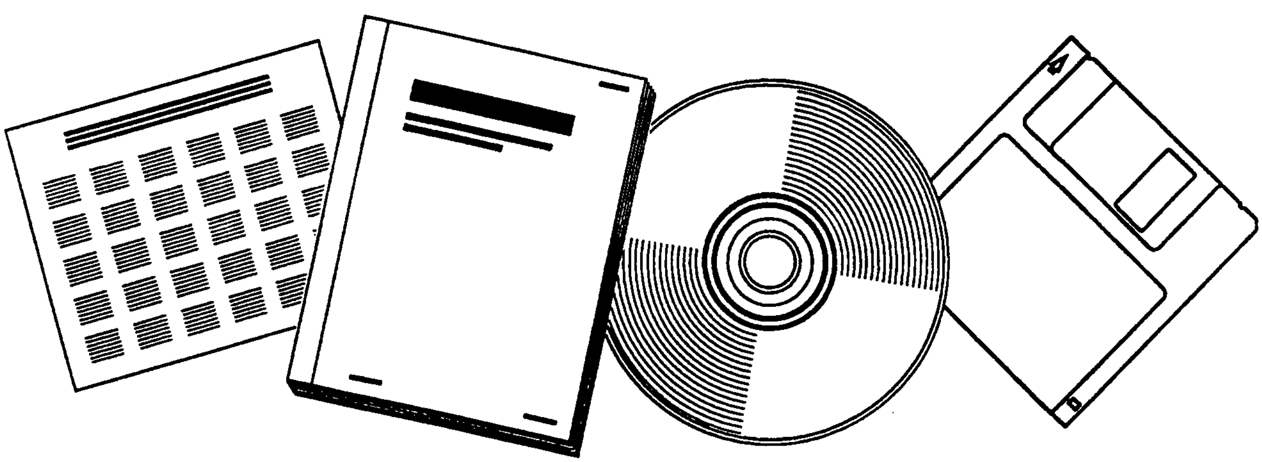
PB98-110091

JOURNAL OF PUBLIC TRANSPORTATION. VOLUME 1, NO. 3

1997



U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

JOURNAL OF
Public Transportation
Volume 1, No. 3, Spring 1997

National Urban Transit Institute
Center for Urban Transportation Research
College of Engineering • University of South Florida
4202 E. Fowler Avenue, CUT 100, Tampa, FL 33620-5375
(813) 974-3120 • Fax (813) 974-5168
E-mail: *phenders@cutr.eng.usf.edu*
Web Site: http://www.cutr.eng.usf.edu

Public JOURNAL OF Transportation

Volume 1, No. 3, Spring 1997

Contents

"Our troubled planet can no longer afford the luxury of pursuits confined to an ivory tower. Scholarship has to prove its worth, not on its own terms, but by service to the nation and the world."
— Oscar Handlin

Implementing Organizational Change through Visioning and Strategic Planning– The CTTransit Experience

Michael A. Sanders
Connecticut Department of Transportation
David A. Lee
CTTransit

Abstract

*A visioning and strategic planning process was undertaken at **CT**Transit beginning in early 1995 that has resulted in fundamental changes in organizational goals and values. A critical aspect of the visioning process was the involvement of union leaders and officials from the Connecticut Department of Transportation (CDOT), as well as the transit system's management, in articulating a shared vision of the future. The new vision has helped to transform the organization from one that was historically reactive and conservative to one that is proactive both in responding to customers and embracing technology. A variety of projects and interdepartmental teams have been organized to carry out five strategic goals for the organization. Parallel changes in CDOT's Bureau of Public Transportation have been implemented.*

Introduction

Beginning in early 1995, **CT**Transit undertook a "visioning" process that has produced a profound transformation of organizational values and a "rethinking" of goals for the future. Of particular importance has been the involvement of CDOT and local union officials in the visioning process.

Corporate America has long relied upon various tools and techniques to restructure management and help businesses chart their future courses. From management by objectives to strategic planning to total quality management to visioning, all of these processes ultimately serve several basic functions:

- to systematically analyze the conditions affecting an organization;
- to define the organization's mission;
- to articulate the organization's basic values;
- to reach consensus on a desired future;
- to distill the organization's values and future vision into a set of strategic goals;
- to develop an agenda of priority actions to achieve the organization's goals;
- to marshal and allocate the resources necessary to implement action plans; and
- to measure performance toward the accomplishment of the organization's goals and, when necessary, adjust the actions.

There have been numerous noteworthy examples of these processes at work within major U.S. corporations. For instance, several years ago, Sears Corporation diversified its lines of business in order to become the provider of a broad family of consumer services. More recently, Sears announced a new corporate vision that resulted in spinning off subsidiaries such as insurance and real estate companies in order to refocus on its "core business" as a retailer.

The application of strategic management practices to public agencies generally—and to public transit organizations in particular—is not new. Long-standing federal transportation planning requirements have necessitated that local officials envision future service levels and capital needs. Other initiatives, such as Transportation System Management (TSM), planning to comply with Clean Air Act requirements, and "welfare to work" policies, have broadened the mission of transit agencies from merely operating vehicles to serving as instruments of public policy in diverse areas.

About CTTransit

CTTransit is the State-owned bus transit system operating in the Hartford, New Haven, and Stamford urbanized areas. CDOT contracts with a private firm, Ryder/ATE, to provide day-to-day management of system operations. The resident management team reports directly to CDOT staff within the Bureau of Public Transportation's Office of Transit and Ridesharing. There is no separate board of directors or other direct oversight of the transit system by city or regional bodies. **CT**Transit operates a total fleet of approximately 375 buses; employs more than 825 operators, mechanics, and office staff; and administers an annual operating budget of $54 million.

CT TRANSIT

Strategic Planning Among Transit Systems

Most public transit systems have practiced strategic planning techniques on a more or less formal and/or comprehensive basis. Articulating a mission statement and overall goals and objectives is very useful for building teamwork and developing a sense of common purpose among employees. Strategic planning is often combined with the annual budget process in order to prioritize resource allocations and adopt performance benchmarks. Input to the federally-required, multi-year Transportation Improvement Program likewise provides a framework for future planning on a broader, regional scale.

These processes are usually suitable for organizations whose value systems, missions, and goals are relatively stable and constant over time. This is because conventional corporate planning practices tend to take the existing organizational structure and mission statement as givens. The experience of **CT**Transit was for management by objectives and annual action planning to reinforce basic company-wide values (e.g., emphasis on adherence to procedures vs. risk-taking, antipathy to unproven techniques vs. pioneering new technology, etc.). In addition, by focusing on projects to be completed by existing organizational units (e.g., maintenance, human resources, transportation, etc.), the process reinforced the existing organizational structure. Thus, for example, the action planning process worked best on solving problems within work units; it militated against interdepartmental teaming as a strategy to address company-wide objectives.

Visioning

Although some have derided visioning as simply the latest in a long line of corporate planning fads, others see the process as an evolutionary step up from traditional strategic management. At its heart, the process seeks to build consensus on a shared "vision" of the future that is unconstrained by existing goals and structures. The vision is described in terms that articulate organizational values and aspirations. Goals and objectives are by-products that flow from the vision, rather than direct products of analyzing problems (the current euphemism is "challenges").

The foundation of visioning is this exercise: "Describe our organization as you would like it to be in the future." One important technique is to express elements of the vision only in positive terms. That is, the process strives for consensus on what the desired future should be, not merely on what present conditions should be changed. In effect, participants are challenged to focus on what the desired future will be like, rather that on what present problems will be solved. For example, a vision statement might include the statement, "Our outstanding service reliability contributes to a high degree of customer satisfaction," rather than "Missed trips due to roadcalls have been reduced."

The latter distinction is subtle, but central, to visioning as a process for transforming organizational values. Conventional management by objectives techniques tend to focus on specific problems and, in doing so, on distinct organizational units—for example, "Roadcalls are a maintenance problem. Reducing roadcalls will be the Maintenance Department's objective this year." Visioning challenges the entire organization to recognize that reducing roadcalls is not an end unto itself. Roadcalls can be reduced, but at what cost financially and organizationally? Do other functions suffer in order to meet a goal that in and of itself does not necessarily reflect quality of service or quality of maintenance effort?

Even the objective of improving service reliability is not an end unto itself. Rather, the ultimate goal is to achieve a high degree of customer satisfaction, in part, by operating a highly reliable service. Service reliability becomes an organizational value in which every employee and every department have a stake—and to which most employees and departments can contribute somehow. It is no longer just a "maintenance problem."

Visioning also can help an organization broaden its horizons. Strategic planning techniques that basically build upon an assessment of current organizational strengths and weaknesses are more likely to reinforce the existing organizational mission. By contrast, visioning encourages the organization to at least explore the possibility of broader and more diverse functions. For example, there is a subtle, but critically important, distinction between a transit system whose basic ethos is that of "bus operator" versus a system whose ethos is that of "mobility provider." Likewise, an organization can envision its mission in terms of the public policy goals it serves, rather than just the functions it performs.

Visioning Process at CTTransit

Prior to 1995, **CT**Transit used an annual Action Plan process to set priorities and allocate internal resources. The plan included some systemwide projects, such as replacement of fare collection equipment and preparations to host the Special Olympics World Games in New Haven. However, most Action Plan projects were carried out within individual departments and were usually exclusive to that one operating unit. In reality, the Action Plan became a "to do" list for a unit, but not necessarily with the whole company in mind.

The Action Plan lacked the vitality that comes from interdisciplinary thinking and a common vision. The role of **CT**Transit as "merely a bus operator" was emphasized and was reinforced to some extent by long-standing direction from the system's owner, CDOT. But, by early 1995, several forces had converged that warranted a different approach to strategic planning within **CT**Transit.

For the first time in several years, there had been changes in the makeup of both the **CT**Transit management team and key officials in the CDOT Bureau of Public Transportation that motivated a reappraisal of the system's goals and objectives. A fundamental part of the change was an insistence that **CT**Transit and CDOT management provide proactive leadership for the system, and not merely act as stewards. The new CDOT administrators made clear their expectation that transit management adopt a new direction and a new style of leadership.

Also, for the first time in several years, **CT**Transit had experienced a significant decline in ridership, especially in the Hartford area. Service levels, ridership, and fares had remained remarkably stable throughout the 1980s. The ridership decline experienced in the early 1990s warranted a redirection of service planning and a new emphasis on marketing and market research techniques in order for the system to survive and maintain a meaningful public service role.

Finally, major capital development programs, which occupied the energies of system management and CDOT officials during the 1980s, were largely complete. By 1995, all of **CT**Transit's pre-1988 bus fleet had been, or was in the process of being, replaced. The modernization of operating facilities in Hartford and Stamford and the acquisition of major new radio communications, fare collection, and computer systems were also completed.

CTTransit thus enjoyed a heretofore unavailable opportunity to market attractive bus service to the public and address the external challenges of the changing role of transit in its service areas, while working with supportive leadership, albeit in a severely-constrained fiscal environment. In one sense, **CT**Transit is unique because the transit system's management team reports directly to CDOT staff, rather than to elected officials or a publicly-appointed policy board. This arrangement certainly facilitated the visioning process, once the CDOT officials involved had recognized a need for change. However, there is no reason why another transit system with a more conventional type of policy board could not similarly pursue a visioning process.

In February 1995, a retreat unprecedented in the history of **CT**Transit was held that involved all members of the executive management staff, business agents from the three union locals representing **CT**Transit drivers and mechanics, and key staff from the CDOT Bureau of Public Transportation. A professional outside facilitator was engaged to lead the attendees through a two-day, off-site visioning process. Putting all the players together in the same room was historic. Sharing thoughts, ideas, and desires for the system within this group for two days was often revealing, and sometimes painful.

Involving union leaders from the beginning was essential to help communicate the organizational vision to rank and file employees. While **CT**Transit had a previous track record of involving union employees on project groups that targeted single issues, this was the first time that union leaders had been involved in real policy planning. The union leaders who attended the retreat readily appreciated that a continuing ridership decline negatively affects all employees. Thus, they were strongly supportive of a vision they felt could only mean more work— and more prosperous working conditions—for their members.

If anything, the "painful" aspect of engaging in a candid reappraisal of organizational aspirations and values was having to question what some felt were "tried and true" management principles (e.g., "if it ain't broke, don't fix it"). Ultimately, when everyone accepted that the status quo could not endure, that CDOT officials expected change, and that not changing would ultimately prove more painful than changing, major progress towards articulating a shared vision of the future began.

That meeting formally began a new era for **CT**Transit. In many respects, what ensued over the following 20 months was more important than what actually took place during the retreat. However, in the course of having each attendee articulate his or her image of a future **CT**Transit, and in crafting a new mission statement for the organization, consensus through communication and compromise emerged on a shared vision of the future that broke dramatically with past goals and strategies in several key areas.

Historically, one of the principal marching orders for **CT**Transit management was to "serve demand." In effect, **CT**Transit would provide service for existing customers, but would not set out to develop new markets or market new services. The new vision embraced the concept of implementing a pro-active and market-driven approach to service planning and marketing, including special emphasis on market research techniques to identify potential customers and communications techniques to enhance the public image of transit.

Similarly, **CT**Transit was not historically renowned for technological leadership. Some unfortunate experiences with new buses and fare collection equipment in the late 1970s created an atmosphere that did not welcome "cutting edge" technology. In other areas, such as the radio system, **CT**Transit enjoyed relatively new, but also relatively old-fashioned, equipment. The new vision embraces technological solutions and promotes **CT**Transit's role as a technical services leader for transit in Connecticut.

The key values that emerged from the visioning process were distilled into the following "Vision Statement" for **CT**Transit:

> **We envision CTTransit being one of the premier transportation systems in the United States. There are four key dimensions of this vision:**

- **We are pro-active in effectively developing and marketing services for current and potential customers.**
- **We are recognized as an industry leader in applying state-of-the-art technology to improve the quality of service and efficiency of operations and administration.**
- **CTTransit management is recognized for bold, innovative leadership that is highly respected both within and outside the organization.**
- **We are successful in fulfilling our mission to work together to move people on a high quality system that is safe, reliable, and efficient.**

A key element in the visioning process was to update CTTransit's long-standing Mission Statement. The final key dimension above contains several subtle, but very significant, changes. In particular, the former mission statement emphasized "operating service," whereas the new mission emphasizes "moving people." This change reflects a recognition of the role CTTransit can play as an instrument of larger public policy efforts to improve urban mobility and enhance the efficiency of the entire transportation system.

The revised mission statement also emphasizes "working together." This emphasis reflects the participation of labor, management, and government that is central to realizing the vision for the future. It also underscores a commitment to use more interdepartmental mechanisms, rather than to compartmentalize action planning within existing organizational units.

It has been observed that the Vision Statement makes no direct reference to "customer satisfaction." This was not a deliberate omission. Perhaps customer satisfaction was not mentioned because it was already perceived to be a major strength of the transit system. Or, perhaps, satisfaction as a "measured" perception by the customer was not the visionary ideal, but, rather, the vision was to provide a high-quality and customer-focused product. In any event, customer satisfaction will continue to be measured and tracked as a performance indicator.

Strategic Goals and Action Plans

After consensus was reached on the vision and mission statements, the next step was to develop a set of strategic goals. These represent priorities to fulfill the vision, around which specific action plans are developed and prioritized. For **CT**Transit, five specific strategic goals were identified. In order to communicate the goals effectively to all employees, each was described with a shorthand slogan, as follows:

Attract New Customers. Implement a pro-active and market-driven approach to service planning and marketing.

Get Our Message Across. Promote a positive public image with improved, user-friendly communications.

Be a Technical Services Leader. Establish **CT**Transit as an industry leader in such areas as maintenance skill training and development of an in-house research and testing capability.

Embrace New Technology. Develop and implement a long-range capital plan emphasizing opportunities for technological innovation to improve the efficiency of operations and administration.

Stress Safety. Increase safety and security of people and property.

A brainstorming approach was used to identify lists of possible projects or action plans that could contribute to achieving each strategic goal. For example, possible projects to enhance the public image of **CT**Transit included improved complaint-handling procedures, increased coordination of transit and ridesharing promotions, improved signage and passenger amenities at bus stops, and a new, bolder corporate logo and paint scheme. Possible projects to establish **CT**Transit as a technical services leader include developing a Connecticut Transit Technical Institute within the Maintenance Services Department, promoting technical training for both **CT**Transit employees and other systems, and encouraging partnerships with Connecticut industry, universities, and other agencies to demonstrate new technologies.

The next step was to appoint cross-organizational teams to further refine and prioritize projects for each strategic goal and to identify preliminary budgets, funding sources, implementation schedules, and performance milestones. Within CTTransit it was especially important to ensure that these teams provide opportunities for staff from different departments to participate in a joint effort along with CDOT and union representatives. Bargaining unit employees are paid for their time serving on committees.

The technology-oriented goals mainly lent themselves to specific projects, while planning and marketing goals lent themselves to ongoing working groups. The safety-related goal lent itself to a combination of both approaches.

Implementing Technology Goals

Specific projects to implement the goals of "Become a Technical Services Leader" and "Embrace New Technology" include the following:

- *Emissions Testing of EPA Approved Engine Rebuild Technologies*—CTTransit became the first transit system in the country to install and test Englehard and Johnson-Matthey catalytic mufflers for heavy duty urban transit buses.
- *Upgrading of Chassis Dynamometer to Simulate Actual Driving Conditions*—This project is currently under way for completion scheduled in 1997.
- *Demonstration of Small Specialty Coaches*—This project is also currently under way, awaiting final approval of FTA funding.
- *Expansion of Maintenance Training Programs*—CTTransit has received national recognition for in-house training on basic AC electricity, braking systems, and steering. During 1996, in-house training programs were offered at cost to employees of other State-funded transit operations.
- *Implementation of a Maintenance Apprenticeship Training Program*—This provision was successfully negotiated as part of a new union contract agreement in 1996.
- *Implementation of Cooperative Research Projects with Connecticut Industries and Education Institutions*—CTTransit has worked closely with

International Fuel Cells in their federally-funded project to develop a prototype fuel cell powered bus. **CT**Transit also has continued to work closely with the University of Connecticut's Transportation Institute to implement a curriculum of training for transit managers.

- *Implementation of Technology Application Projects through the Capital Budget*—Ongoing projects include upgrading the computer networks in all divisions, automating dispatch and timekeeping functions, expanding the laserdisc digital photolog of bus routes, upgrading scheduling and customer services computer systems, implementing a fully automated fluids management system, and implementing a Maintenance Reference Display System (replacing repair manuals with information available on CD-ROM).

Other projects to be implemented in 1997 and future years include establishing a **CT**Transit Technical Institute, investigating the feasibility of AVL technology, developing the capability for on-line passenger information, and expanding applications for bar coding technology in the maintenance area.

Implementing Planning and Marketing Goals

Five teams have been established to coordinate a wide variety of activities to achieve the Strategic Goals for planning and marketing. It has been especially important in organizing the teams that members are drawn from different levels and units of the organization, from CDOT staff, and even from outside the organization (for example, the general manager of a major suburban shopping mall has been an active member of the Service Design and Development team). All participants attended a special day-long training on the teaming process. The teams' accomplishments to date are summarized below.

Business Development

This team focuses on how to increase ridership by working cooperatively with employers and retailers. The team's efforts were instrumental in establishing a full-time Business Development function within the **CT**Transit staff and planning a series of co-promotions around the theme "Our customers are your customers and employees."

Customer Service

This team's first project is focused on designing a more customer-friendly timetable format.

Service Design and Development

This team's first project resulted in the recent implementation of **CT**Transit's first new local bus route in more than 15 years to provide improved suburb-to-suburb service and more convenient transfer connections to the Hartford area's fastest growing retail and employment hub.

Bus Stop Amenities

This team focuses on how to respond more effectively to customers' desire for weather protection, security, and information at bus stops and to appreciate bus stops as "portals" to the transit system. As a result of this team's efforts, a proposal to implement a regional passenger waiting shelter program financed with advertising revenue is being developed for presentation to the Council of Governments' Transportation Committee in the Hartford area.

Express Service

This team's first project has developed a recommendation to extend the "guaranteed ride home" program to monthly bus pass riders on **CT**Transit's premium-fare express services.

In the future, other possible issues to be addressed with the teaming process could include fare simplification, transfers with other carriers, paratransit, and outreach to community groups.

Implementing Safety Goals

For the "Stress Safety" goal, a combination of current projects, new projects, and ongoing working groups have been implemented.

Current projects include a demonstration of bus on-board video equipment, the "Safety Sweepstakes" program for operators, a campaign to reduce the incidence of multiple-claim accidents, and participation in a study to reduce injuries by designing a new bus operator's workstation using ergonomic principles.

About the Authors

Michael A. Sanders has served as Transit and Ridesharing Administrator for the Connecticut Department of Transportation since 1994. His responsibilities include policy and administrative oversight of State programs in urban and rural transit, Americans with Disabilities Act paratransit, ridesharing and transportation demand management, as well as motor transport regulatory and administrative law programs. He holds bachelor's and master's degrees in Geography from Binghamton University and a Master's in Business Administration from Pace University in White Plains, New York He is a member of the Board of Directors of the American Public Transit Association, Region I, which encompasses the New England states and New York.

David A. Lee is an associate of Ryder/ATE Management and Service Company and currently serves as General Manager of **CT**Transit. He joined the management team at **CT**Transit in 1983 as Assistant General Manager for Administration and was AGM for Transit Operations from 1991 to 1995. He holds a bachelor's degree from Colgate University and a master's degree in political science from the George Washington University and is the Immediate Past President of the New England Passenger Transportation Association.

Findings from a Survey on Bus Stop Design

Kay Fitzpatrick
Dennis Perkinson
Kevin Hall
Texas Transportation Institute

Abstract

The bus stop is the first point of contact between the passenger and the bus service. The spacing, location, and design of bus stops significantly influence transit system performance and customer satisfaction. At present, relatively few transit agencies have comprehensive reference material available to assist in bus stop location and design. In recognition of the importance of bus stop location and design, the Transit Cooperative Research Program (TCRP) sponsored research to develop guidelines for locating and designing bus stops in various operating environments. These guidelines can assist transit agencies, local governments, and others (e.g., developers) in locating and designing bus stops that consider bus patrons' convenience, safety, and access to sites, as well as safe and efficient transit operations and traffic flow.

Mail-out surveys were conducted as part of the TCRP bus stop location and design guidelines project. The mail-out surveys, which were an initial task of the project, were used to determine current practices and areas of concern regarding bus stop design for transit agencies and states. Less than half of the responding transit agencies currently use guidelines or manuals, which indicates a need for the document being developed. Furthermore, almost every agency has moved a bus stop to improve

were completed, for a response rate of 35 percent. The state survey was mailed to the 50 states, Puerto Rico, and the District of Columbia. Of the 52 state surveys mailed, 26 were completed, for a response rate of 50 percent. The following provides a section-by-section synopsis of the survey results and also notes significant findings.

General Information

The initial section of the survey provided an overview of certain elements within a transit agency or state, such as the use of guidelines and bus stop redesign or relocation experience.

Use of Existing Guidelines

In order to determine the current extent of guideline usage, the first question asked whether transit agencies use specific guidelines or a manual when they locate and design bus stops. Less than half (44 percent) of the responding transit agencies use guidelines or manuals, and two-thirds (65 percent) of the responding state agencies do not use guidelines or manuals. Publications were provided by 20 of the transit agencies responding to the survey, and an additional 11 provided information on the materials they use.

Redesign and Relocation Experience

A separate question asked about the extent and frequency of the redesign or relocation of existing bus stops. Almost every transit agency has moved a bus stop to improve traffic operations; however, only slightly more than half (58 percent) of the responding agencies have redesigned a curbside stop to a bus bay or nub design. (A bus bay is a specially constructed area off the normal roadway section provided for bus loading and unloading. It is also known as a turnout or duck out. Nubs are bus stops where the sidewalk is extended into the parking lane, which allows the bus to pick up passengers without leaving the travel lane. Nubs are also known as bus bulbs or curb extensions.) Half (50 percent) of the states have moved a bus stop to improve traffic operations, and just over one-third (38 percent) have redesigned a curbside stop to a bus bay or nub design.

Approximately one-third (38 percent) of the states and 40 percent of the transit agencies have used bus priority measures such as restricted bus only lanes and signal pre-emption.

Other Information

Due to the emphasis in this project on high speed roadways, a question was included to determine whether the transit agency has bus stops located on roadways with an operating speed of 45 mph or above. Approximately three-fourths of the agencies responded "yes" to this question. Other information requested included consideration of pavement requirements and the use of data bases to manage bus stop facilities. Special consideration for the pavement in bus stop and layover locations was provided by 60 percent of the respondents. Data bases are used to manage the bus stops by approximately 60 percent of the agencies.

Bus Stop Configuration

A separate section of the transit agency survey provided information on the frequency of use of different types of stops. The results show that both far-side and near-side stops are commonly used, while midblock stops are rarely used. The distribution of responses for the use of far-side and near-side stops are similar, which indicates that certain transit agencies prefer one type of stop over the other (and that the debate between which is better—far-side stops or near-side stops—will continue).

Nearly all of the transit agencies surveyed use curbside stops over the bus bay and/or nub design. With a value of 5 representing that the design is always used, 94 percent of the agencies marked either the 4 or the 5 value for curbside stops. For bus bays, 79 percent marked never (value of 1) or almost never (value of 2), while 94 percent marked similar answers for the nub design.

Transit agencies that use bus bays indicated that acceleration and deceleration lanes are rarely used in bus bay designs. Less than 25 percent of the respondents gave a 3 or higher response to this question. Clearly, the most common type of bus stop is the curbside stop; however, this survey along with field observations indicate that bus bay and nub designs are strongly considered and used.

Table 1
List of Possible Key Factors

ADA access	Pedestrian access
Anticipated delay to major roadway vehicles	Petition and/or complaints
Anticipated delay to buses	Proximity to land uses
Area type (retail, residential, suburban, etc.)	Ridership (boardings and alightings)
Auto parking availability	Route type (e.g., express, local, etc.)
Headway (time between bus arrivals)	Signal location and timing
Neighborhood support positions	Shoulder conditions
On-street parking	Traffic control devices
Passenger safety and security	Traffic volume on roadway
Pavement design	Transfers (number of routes)

The following factors received a "number one priority" in terms of bus stop spacing decisions, street-side, and curbside design. (Numbers indicate the number of respondents assigning top priority to the factor.)

- Spacing Between Stops:
  - Area type (22)
  - Ridership (13)
  - Pedestrian access (10)
  - Route type (9)
  - Passenger safety (9)
- Street-Side Design:
  - Passenger safety (22)
  - ADA access (15)
  - Traffic volume (9)
- Curbside Design:
  - Ridership (24)
  - ADA access (24)
  - Safety (13)
  - Pedestrian access (9)

In general, area type is far more important in the spacing/placement stage of stop design than in the later stages. Ridership is an important consideration both at the spacing stage and even more so in considering curbside aspects. Not unexpectedly, traffic operations factors are of greatest concern in considering street-side aspects of stop design. Safety and security were also important. ADA considerations are particularly important in curbside and street-side decisions. Public input and furniture issues were of least importance in location and design decisions at any of the stages.

Additional Comments

At the end of the survey instrument, concerns and comments were solicited, and space was provided for their inclusion. Since any information provided was entirely optional and totally unstructured, the responses were diverse.

Of particular interest were comments suggesting several areas to avoid in developing bus stop location and design guidelines. One common theme was the caution to avoid too structured a final document. There was concern that bus stop decisions are very site specific and do not lend themselves to too much formalization. The research team was urged to maintain flexibility in the developed guidelines. Another expression of the same idea involved cautioning the project team not to try to determine whether far-side or near-side stops were better.

At the transit agency level, several transit agency respondents specifically mentioned their need for help with meeting ADA requirements, either in gaining a better understanding of exactly what is required, an interest in learning what others are doing, or concerns over the magnitude of the challenge of ADA compliance.

At the state level, several states responded that they had no control over any issue listed or that bus stop design is handled by the transit authority with local government coordination. Other states assist with design only if the design is a part of a state highway project, or they issue permits or participate in the bus stop design if it is on a state route or is part of a grant project. Several states re-

Feasibility of Advanced Vehicle Control Systems (AVCS) for Transit Buses

Robert A. Larsen
Raytheon-E Systems

Abstract

In the course of developing automated vehicle-roadway systems, opportunities to deploy vehicle control systems at intermediate stages of development may emerge. Some of these systems may provide a significant efficiency or safety enhancement to existing operations with manually-driven vehicles. Under certain circumstances, transit buses provide an ideal testbed for such systems. The work presented here represents a feasibility study for the application of Advanced Vehicle Control Systems (AVCS) to transit bus operations. The paper explores past and present research relevant to automatic control for buses and describes specific operations that could be better performed by AVCS-assisted or controlled vehicles.

The study concludes with a series of recommendations for proceeding toward a deployment phase. For transit bus operations, the most suitable deployment opportunities for AVCS exist on exclusive busways (bus-only roads) or large bus servicing facilities used for daily maintenance operations. Busways would provide an excellent testing ground for a lateral control/lane keeping system. Such a system would provide immediate utility on the existing busway and would serve as a building block for more highly automated systems in the future. Maintenance operations in service garages require dedicated drivers to move vehicles through a routine servicing sequence. By fully automating the movement of buses within such facilities, labor costs could be dramatically reduced.

AVCS in Transit Buses–A Background

While vehicle control has been extensively developed for rail/guideway-based vehicles like trains and Automated People Movers (APMs), relatively little automation technology has been applied to buses. Likewise, despite underlying similarities among buses, automobiles, and trucks, the significant work performed in vehicle control for passenger cars (and to a lesser degree trucks) has largely gone untested for buses. On the one hand, this is surprising, given the sensitivity of transit operators to incremental improvements in operating efficiency—improvements that appear achievable through the application of AVCS. On the other hand, there is typically little funding available for the development of new transit technology, with available funds more likely spent on low-risk systems that show a more immediate return on investment. In addition to concerns regarding the cost-effectiveness of AVCS, there are many legal and institutional questions surrounding AVCS and vehicle automation—for example, liability issues in the case of accidents, as well as passenger and driver fears associated with the replacement of drivers by computers.

There is, however, a small body of work in transit bus guidance that demonstrates some of the potential benefits to be derived from AVCS. The most significant work has been demonstrated by the O-Bahn system, deployed in Adelaide, Australia; Essen, Germany; and the United Kingdom. The system provides automatic lateral control on express segments of the bus route and conventional (manual) vehicle control elsewhere. Special bus and roadway modifications are required for automatic operations. Both mechanically- and electronically-guided systems have been deployed since the late 1970s; however, the mechanically-guided systems are much more commonly found in service. The mechanical system is guided by horizontal rollers connected to the steering linkage and projected from the sides of the bus, bearing against tall curbs. The electronically-guided bus follows a current-carrying wire in the pavement using an inductive guidance principle. Similar in principle to conventional bus operations on exclusive bus lanes, the O-Bahn buses run on uncongested busways when under automatic control and on the conventional street network when under manual control, providing benefits of rapid transit performance on line-haul segments and flexible collection/distribution service elsewhere. Furthermore, since the guided buses deviate only slightly from their busway lane, only a very narrow right-of-way is required. This allows for lower infrastructure costs and the ability to construct busways where very little space is available (particularly valuable for bridge and tunnel applications). As a result, O-Bahn systems may be viewed as a favorable alternative to light rail in some transit corridors. The ability to run in narrow rights-of-way may also allow guided buses to share subway rights-of-way with trains. This capability was demonstrated in Essen, allowing improved bus service in the downtown area by taking the buses off the congested surface streets and running them in underutilized rail tunnels.

In parallel with the work in guided buses has been the development of Automated Guideway Transit (AGT) systems. While these systems have been demonstrated using a wide range of vehicle and guideway designs significantly different than those used for bus systems, AGT's set a precedent for unmanned, fully autonomous transit vehicle control. Some notable examples of such systems have been deployed at airports around the world (Denver, Orlando, Chicago, etc.). Similar systems have been deployed in cities such as in Detroit, Miami, Lille (France), Vancouver, and London.

Personal Rapid Transit (PRT) concepts involving the use of small, automated guideway-based vehicles serving a dense network of origins and destinations have been investigated for at least 30 years, but the last few years have shown a renewed interest in these concepts as traffic congestion has worsened and technology has improved. Raytheon Electronic Systems of Marlborough, Massachusetts, is currently building a small PRT system for Northeastern Illinois Regional Transportation Authority (RTA) in Rosemont, Illinois, and feasibility studies of other systems are under way around the world. As an automated public transportation system, there are parallels between PRT and AHS (automated highway system) transit, but unlike mass transit, PRT attempts to provide automobile-like service, with very small vehicle capacities and point-to-point service.

Benefits of AVCS for Transit Buses

In assessing the benefits of AVCS for transit buses, a review of existing transit bus operations was performed. From literature reviews, system tours, and interviews with transit experts, several operational areas emerged as suitable for AVCS improvement:

- lane keeping
- longitudinal control
- curbside docking
- maintenance operations
- collision avoidance

Each of these operational areas and the associated AVCS benefits are discussed below.

Lane Keeping

The performance of the lane-keeping task, common to all roadway vehicle operations, is more critical for wide vehicles like buses and trucks than for automobiles since lateral distances to the lane edges are reduced. Lane-keeping systems have been prototyped to provide various degrees of lane-centering control, ranging from driver warnings to full steering control. The value of a lane-keeping system exists for all road-going vehicles, particularly as an aid to driver inattention where lane changing is infrequent, such as freeway driving. However, there exist specific operations for transit buses that could be substantially improved with the aid of a lane-keeping system.

One example is operations in tunnels or other narrow segments of the bus right-of-way. Operations on these narrow segments require drivers to trade-off operating speed for safety. Our research found a substantial number of major transit bus operations with one or more narrow segments where buses must reduce speed or stop to ensure safety; a lane-keeping system does not need to be continuously engaged to provide benefits. A fatal 1996 head-on collision between two buses on a Pittsburgh busway can attest to the importance of the lane-keeping function.

Other benefits of a lane-keeping system could accrue as the transit system infrastructure adapted to take full advantage of the bus's lateral control capabilities. Land acquisition and construction costs would be reduced where guided busways or segments are built as a result of reduced lane-width requirements. This advantage for laterally-guided buses would be most significant where adding or reallocating bridge or tunnel right-of-way is necessary.

Longitudinal Control

Operations that would benefit from the application of longitudinal control may take one of two forms: general automatic speed control or the special case of platooning. General automatic speed control would be employed to maintain desired headways between buses precisely for high frequency service (greater than 30 buses/hour) where slight headway variations could severely disrupt operations. Platooning represents the high frequency operational limit of speed control where headways approach several seconds or less. Longitudinal control systems employ sensors, typically vehicle-based, to control automatically the throttle and/or brakes, and, thus, vehicle speed. In the special case of platooning, a forward-looking radar, ladar, or other sensor, would be mounted on a bus to determine distance and closing rate with respect to the bus immediately ahead. The efficiency advantages of platooning vehicles are clearly demonstrated by the superior productivity of trains relative to buses on high-passenger-demand routes.

Perhaps the only U.S. operation of sufficient scale to justify platooning operates on the Lincoln Tunnel exclusive bus lane connecting northern New Jersey and Manhattan. Assuming available capacity in the Port Authority Terminal for additional incoming bus volumes, there exists the potential to expand the capacity of the bus lane further by applying longitudinal control systems to maintain very short headways safely between buses and keep the bus flow steady.

In the long term, a successful demonstration of platooning on an express lane might motivate transit planners to consider dedicated guided busways with bus platoons as an alternative to light rail in more heavily traveled corridors.

This system conceivably could be demonstrated to run trains of buses under lateral and longitudinal control with a single lead driver (or perhaps no driver), to reduce labor costs significantly. Such a system could approach the operating efficiency of trains on moderately high-volume routes while utilizing much cheaper vehicles with the flexibility to be run on conventional roads. Autonomous vehicle-following technology has been demonstrated successfully for several years by various research institutes and vehicle manufacturers, including Daimler Benz, Carnegie Mellon University, and the National Institute of Standards and Technology (NIST), among others.

While the Lincoln Tunnel case would provide an opportunity to demonstrate longitudinal control to improve the capacity of an express segment of a bus route, much shorter platoons also could provide capacity benefits for non-express operations. The concept of a "virtual artic" (two or three platooned buses that move as a single bus with the passenger-carrying capacity of a single or double articulated bus) comes to mind. On some routes or route segments, it may be advantageous to utilize the operational efficiency of large capacity vehicles, even if each vehicle still retains a driver onboard.

Short of automatic platooning, a speed control system to precisely maintain short headways of approximately one minute or less would be advantageous on some high-volume transit lines. This approach could help to reduce the problem of bus bunching that often occurs on such routes when one bus slips from its schedule and following buses "close the gap" from behind.

Curbside Docking

The presence of a gap or height differential between bus doors and the curb/platform area causes inefficient and inconvenient operations at bus stops. The provision of a level loading surface without gaps allows for much easier passenger access/egress and thus minimizes dwell time at stops. Another significant advantage for level loading is the improved access for the physically disabled. Level loading buses also eliminate the need for wheelchair lifts, which are expensive, maintenance intensive, and time-consuming to operate. In order to capture the advantages of level loading, however, there must be little or no gap between the bus and the curb, and, thus, automatic control of the bus for precise placement is desirable to ensure consistent and efficient docking. Over the past 20 years Volvo, and more recently, Renault have experimented with automatic bus guidance for this purpose.

Maintenance Operations

From discussions with several transit system operators, it is clear that any incremental reductions in operating expenses would be embraced. A significant number of operators interviewed believe that bus service and maintenance operations could be streamlined with the application of AVCS. Every day, there are routine operations repeated by dedicated maintenance staff who drive buses between stations to perform various tasks. At the end of each bus's service period, the driver takes the bus through a fueling area, a fluids check area, and a washing area, and then parks the bus in a designated space. An alternative to using drivers at each facility would be to move buses autonomously through the facility, either under their own power or by automated tow vehicles (see Figure 1). The relatively controlled environment of the maintenance area combined with the imme-

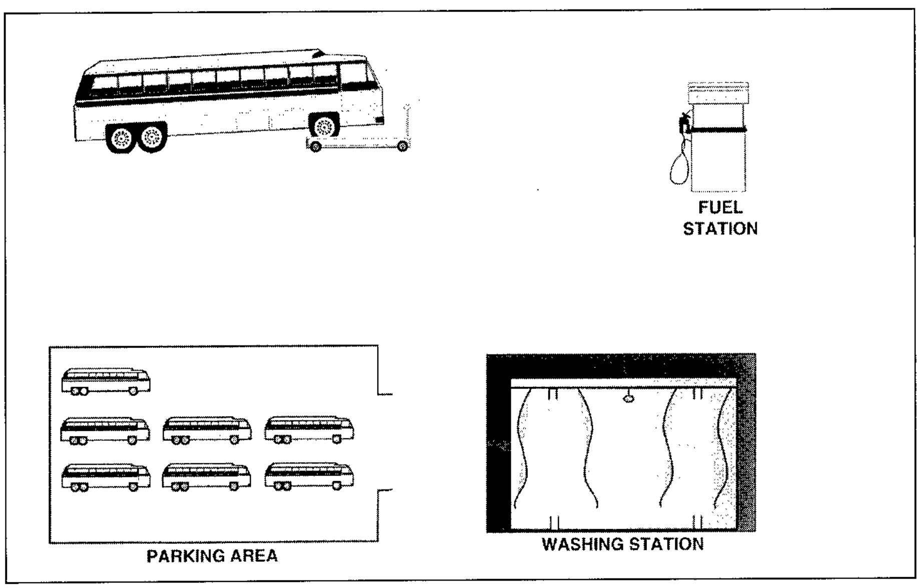


Figure 1. Concept for an automated bus servicing operation.

diate benefits provided by AVCS make this a strong candidate for a system deployment.

The use of driverless tow vehicles, similar to those Automated Guided Vehicles (AGVs) that circulate in factories and warehouses around the world, could provide a direct replacement for maintenance facility drivers. In this scenario, each vehicle would be responsible for moving several buses per hour during servicing periods. Fully-automated buses would not require any dedicated drivers or tow vehicles, but a substantial fraction of the bus fleet would need to be equipped for automated movement to allow for significant operating cost savings.

Collision Avoidance

Like lane keeping, collision avoidance is under investigation for all types of vehicles. Several transit operators interviewed expressed interest in cost-effective collision-avoidance systems, particularly rear-end collision-avoidance systems. The National Highway Traffic Safety Administration (NHTSA) and various automotive manufacturers and suppliers are working actively toward collision avoidance systems to reduce the frequency and severity of a wide assortment of collision types.

Attitudes of Transit Community Towards AVCS

In the course of this research effort, many transit and AVCS studies were analyzed, and various transit industry experts were interviewed, including transit system operators, transit planners, bus manufacturers, transit consultants, and researchers. The question underlying this examination was: What tangible benefits can AVCS provide for public transportation systems? In particular, the focus was to determine feasible and near-term AVCS opportunities for transit buses. Through the course of the study, it became readily apparent that there was very little appreciation within the transit community for the benefits that AVCS could provide.

Once the AVCS concept was thoroughly explained, the overall consensus of the transit community was that AVCS showed exciting potential for the distant future, but much less promise for the immediate future. The more visionary planners imagined dramatic service and operating cost improvements with guided buses running on busways and subway tracks and automated buses moving assembly line-style through maintenance garages, while less optimistic planners did not believe that AVCS could provide many significant benefits, even if the technological and institutional hurdles could be overcome. New technology comes slowly to the transit world, and vehicle control systems are perceived to be several steps beyond the current cutting-edge systems, which are typically information-flow-oriented, like real-time fleet management and traveler information systems. Transit managers cannot afford to be adventurous, either from a cost or operations standpoint, because there is little or no funding available for experimentation, and a system failure is unacceptable to the riders who rely on the service.

Most planners expressed concern that completely unmanned bus concepts would be difficult from a fare-collection and passenger security issue; however, they accepted that these concerns might possibly be addressed, at least in the short term, by providing lower-paid bus attendants on automated buses. Another concern expressed was that automation methods could displace drivers and upset labor relations. While many transit systems demonstrated opportunities for short- and long-term AVCS deployment, it is the long-term deployments (with facilities and vehicles designed to accommodate AVCS) that offer the highest payoffs. Unfortunately, the enabling technologies for the future must evolve from the short-term applications, like lane-keeping and other systems, which may not provide such a high cost-benefit advantage. Even the most pro-technology transit property will require a compelling economic analysis of the costs and benefits of an unproven technology approach like AVCS.

From the industry side, there was also cautious interest in AVCS. A leading transit industry consultant with expertise in the design and deployment of automated guided transit (AGTs) pointed out that with labor typically representing

75 percent of operating costs, any incremental labor cost reduction that AVCS could provide should be considered seriously. He also indicated that it would be important to get the bus manufacturing industry interested in AVCS, as they would obviously need to contribute to the design and production of an AVCS-equipped bus. This may be a challenge because the level of research and development funding is typically very low in the bus industry, and manufacturers would need to see a strong demand from their customers to justify any exploration of AVCS. Several European bus manufacturers, however, have proven their interest in vehicle control technology by deploying guided buses and investing in guidance technology.

Feasible AVCS Technologies for Transit Bus Applications

While this section is not intended to provide an exhaustive or thorough description of all guidance systems available, it attempts to illustrate the most promising technologies for a near-term system deployment. While several distinct systems are described here as alternatives, it is quite likely that the ideal AVCS for a given task will incorporate more than one of these technologies simultaneously.

Wire Guidance

As described previously, the inductive guidance system demonstrated on O-Bahn buses has a long history in vehicle control. This guidance technique, developed more than 40 years ago and widely used in factory automation for automated guided vehicles (AGVs), relies upon vehicle-mounted inductive coils to sense the magnetic field induced by current in the wire. The measured field indicates the distance between the coils and the wire, and, thus, vehicle lateral offset can be implied. Among its technical advantages, wire guidance is robust, proven, and relatively simple. Among its disadvantages, wire guidance is infrastructure-intensive and inherently inflexible, as it requires the presence of a wire path to any location that a vehicle may need to reach.

Passive Magnetic Trails

Like the guided-wire system, the underlying guidance principle of magnetic trails is to provide a path in the pavement for a vehicle to follow easily. Unlike guided wires, however, passive magnetic trails do not require power to provide a guidance signal. Two approaches are currently under investigation: discrete magnetic markers and continuous magnetic stripe. The California Partners for Advanced Transit and Highways (PATH) program based at the University of California, Berkeley has investigated the discrete markers method and has successfully demonstrated its capability for lane keeping. Magnetic roadtape research is underway in Minnesota by 3M. Their work focuses on the incorporation of a magnetic substrate into a conventional pavement marking tape. Like wire-guided systems, magnetic trails may provide reliable and accurate lane keeping, but they are infrastructure-intensive and relatively inflexible.

Differential Global Positioning System

The Global Positioning System (GPS) has been used for several years in the tracking of vehicles, seacraft, aircraft, etc. The system that incorporates line-of-sight communications between orbiting satellites and a receiver anywhere on earth provides positional accuracy on the order of 100 m for general users. To greatly improve accuracy, signal processing enhancements, generally classified as differential GPS (DGPS), have been introduced to correct signal transmission degradation between the satellites and a receiver. Research in recent years has shown that DGPS can provide positional accuracy in the 2 cm range—sufficient to make this technology feasible as a navigation system. While there are disadvantages associated with GPS, its major inherent advantages are high accuracy and existing infrastructure availability (satellites and ground stations). Many in the AVCS community believe that, in the future, DGPS will provide one of the basic guidance technologies for vehicles.

Machine Vision

Image processing techniques have been under development for many years and have been successfully implemented in automobiles and other mobile robots for guidance. Among advantages, machine vision systems require little or no infrastructure modifications, have been shown to provide excellent positional data for vehicle guidance, and may be configured to perform many different tasks (from lane keeping to collision avoidance to road sign reading). Some disadvantages are current system expense, complexity, and inherent limitations of the basic sensor (camera), which can provide information only on the scene immediately visible to it.

Opportunities in Specific Transit Systems

Over the course of several months in late 1995 and early 1996, transit managers at several transit agencies were interviewed to assess their interest in AVCS for transit bus operations. The following is a summary of findings from those discussions.

Pittsburgh

Of transit properties studied, the Port Authority Transit (PAT) system is one of the most suitable for AVCS deployment. PAT operates the only dedicated and grade-separated busways in the country, providing an excellent testbed for vehicle control testing and development. Based on conversations with PAT staff, it appears that they are generally receptive to new technologies that can legitimately reduce operating costs or improve service quality.

Houston

With its well-funded and heavily bus-oriented transit system, Houston is currently the only regional transit agency spending research and development funds on the development of AVCS. Houston METRO is scheduled to participate in the 1997 AHS Demonstration with laterally- and longitudinally-guided buses based on machine vision and forward-looking radar sensors. They have also expressed serious interest in the testing of automated movement of buses within maintenance facilities.

Cleveland

The Greater Cleveland Regional Transit Authority (RTA) staff were interested in AVCS and in new transit technology in general; some were particularly fascinated by the potential of AVCS for RTA's operations. Of particular interest was the maintenance area automated vehicle concept previously described. Interest was also expressed by RTA planners for the Euclid Avenue corridor, which will undergo a major bus transit service improvement in the next several years. An option that may be considered for the corridor is a guided busway, given the very limited right-of-way available.

Seattle

Some features of King County Metro's transit system make it a suitable candidate for AVCS deployment. The unique 1.3-mile bus tunnel/subway and attached busway segment are exclusive bus facilities that show potential safety and efficiency benefits from AVCS. The automated service garage concept was also of interest to Metro planners. Furthermore, the director of King County Department of Transportation (KCDOT) is a strong proponent of new technology for his transit system.

Other Areas

In addition to the specific cities listed above, there are other cities and regions that may also be suitable for an AVCS deployment. In the course of this study, it became clear that transit systems in each city have their own unique opportunities for AVCS, whether it be for narrow tunnel segments, dedicated bus lanes, abandoned or shared rail rights-of-way, or other opportunities. Some of the more promising transit AVCS opportunities exist in such areas as metropolitan New York City, Minneapolis, and Montgomery County, Maryland. An interesting development that may encourage the introduction of AVCS is the increasing popularity of busways. While very few dedicated busways exist in the U.S. today, many transit planners are now considering busways and occasionally guided busways as alternatives in their corridor studies (Boston, Milwaukee, and Raleigh are examples). These bus-only facilities are the most suitable for the adaptation of lateral and longitudinal control systems, as they present a relatively controlled environment for integrating new equipment on buses and the facility itself.

Recommendations for Future Work

From a review of transit industry needs and available AVCS technologies, some recommendations have been identified for continued work in the near term:

Automation of bus movement through service areas in bus garages was the most popular AVCS vision for transit operators. Some managers asked how much a system of this type would cost. This should be a high priority area of study for future work. Specifically, a detailed study of vehicles, facilities, and servicing operations at an interested transit property should be performed, and a small handful of AVCS technology providers should be contacted to work toward developing alternative design concepts and cost estimates for such a system.

A design concept and cost estimate for a lateral control system for lane keeping should be developed. As described previously, there are many potential benefits for lane-keeping systems in the near and long terms as well as many levels of deployment possible, from warning systems to full lateral control. In cooperation with specific technology providers, transit agencies, and bus manufacturers, alternative system concepts should be developed and a cost estimate established for each deployment alternative.

With regard to the second option, successful deployment of a lane-keeping system requires that the system perform as designed and be accepted by the transit industry as a legitimate operational enhancement for buses. To achieve this goal, two parallel paths should be taken to enhance the likelihood of success. The first path should focus on a limited deployment of a system for revenue service operations. It is clear from discussions with transit operators that serious consideration of new technology will follow only from real-world demonstrations. It is proposed that a deployment plan include a single, laterally-guided bus operating passenger service on an existing route/roadway segment. This would provide a relatively low-cost technical feasibility demonstration with real credibility for transit operators.

At the same time, efforts should be made to demonstrate the economic justification for a lane-keeping system. A guided-busway alternative based on modern AVCS technology (lane keeping) could prove superior to typical transit alternatives like conventional busways and rail systems. The reduced right-of-way advantage of a guided busway relative to a conventional busway is highly significant in some travel corridors. This advantage needs to be quantified in economic terms; a thorough analysis of the costs and benefits associated with a guided busway alternative relative to conventional alternatives should be developed for a suitable transit corridor.

Once transit operators are convinced of the technical feasibility and economic justification for lane-keeping systems, it should only be a matter of time before deployment begins.

Conclusion

Through the course of this study, numerous contacts within the transit industry were interviewed, and four major transit operations were toured and reviewed. While tremendous opportunity exists for AVCS in transit, successful implementation will require cautious steps. Short-term benefits of AVCS certainly can be demonstrated with modifications to existing vehicles and infrastructure, but to capture fully the larger, long-term benefits will require that vehicles, infrastructure, AVCS equipment, and many transit agency processes (like route planning, scheduling, and operations) be coordinated as a unified system. In the course of this study, two significant observations have emerged:

- Very little shared knowledge exists between the AVCS and transit communities.
- Like so many other pioneering intelligent transportation systems (ITS) initiatives, the deployment of AVCS for public transit will encounter more significant institutional and legal hurdles than technical challenges.

The importance of the first point cannot be overstated. Effective system design requires understanding the entire system and the interactions between all the components. From a technical standpoint, an effective, large-scale AVCS deployment would require a detailed understanding of issues associated with bus operations, vehicles, infrastructure, sensor technology, control system design, and many other issues. The second point indicates the importance of incorporating many non-technical issues into the design process. There are major financial considerations, as well as legal and institutional barriers. There are transit system managers, transit employees, and the riding public who would all need to accept the changes that AVCS would bring. From the standpoint of the transit management there are many risks associated with AVCS, not the least of which are angry labor unions and law suits in the case of system failure. With so little funding available for new technology at most agencies, there is a high opportunity cost associated with testing relatively unproven technology.

If automated highways and automated transit are to achieve broad public acceptance, the transit bus offers an excellent platform for initial deployment. The basic vehicle and infrastructure already exist, and incremental AVCS deployments like lane-keeping systems can demonstrate real benefits while limiting financial, legal, and institutional risks associated with more extensive deployment scenarios. Ultimately, the evolution of vehicle control systems for buses promises to raise the general level of acceptance of automation technology and allow for the increased mobility, safety, and efficiency that automation provides. ❖

Acknowledgments

The author wishes to thank Dick Bishop and Nick Panebianco of the Federal Highway Administration for their support of this study. Thanks also to Ron Fisher of Creative Transit Alternatives for his substantial input and guidance throughout the program.

About the Author

Robert Larsen is a transportation engineer with Raytheon E-Systems in Falls Church, Virginia, and the principal investigator on an FHWA-sponsored study of advanced vehicle control systems (AVCS). Mr. Larsen holds a bachelor's degree in engineering sciences from Harvard and a master's degree in transportation engineering from the University of Maryland.

Personal Public Transport in Australia: Developments and Prospects

Garry Glazebrook
Booz-Allen & Hamilton (Aust) Limited
Sydney, Australia
Sam Subramaniam
Booz-Allen & Hamilton Limited,
McLean, Virginia

Abstract

The environmental, social, and economic cost of current car dependence is well known. But people tend to be unwilling to forgo the convenience of private transport. Personal Public Transport (PPT) is a new concept combining the environmental advantages of public transport with the flexibility of the car. The key elements of PPT are new multi-hire modes provided by maxitaxis and taxibuses to supplement single-hire taxis and scheduled services; integration of all modes into a single system; and provision of real-time information and booking systems enabling individual passengers to communicate with the transport system, whether they be at home, on street or in transit.

This paper describes how PPT will integrate various technologies, such as automatic vehicle location systems, multi-hire dispatching systems, advanced passenger information systems, and smart card billing systems, together with some of the latest developments in Personal Public Transport.

While the technical aspects of PPT are expected to be solvable relatively easily, establishing a complete PPT system will require institutional and regulatory change and a willingness to innovate by both transport operators and regulators. The paper describes changes occurring in Australia in the taxi and bus industries and in regulatory arrangements that will facilitate PPT, and sets out models for establishing PPT systems. It also assesses the potential for PPT from a marketing perspective and its relationship to new developments in urban planning. The paper concludes with a prognosis of how urban transport systems will evolve under the influence of environmental pressures, social values and technological developments, and of how our cities will emerge from the mass transit and private transport eras of the past to the new era of Personal Public Transport and Personal Rapid Transit.

Introduction

Public Versus Private Transport

Private cars provide their owners with many private mobility benefits, including:

- the convenience of traveling whenever they want,
- the flexibility of traveling wherever they want, and the ability to change their destination easily, and
- comfort, privacy and the ability to travel alone or with people of their choosing.

In addition, the car has often been associated with status, independence, and a feeling of freedom. These mobility and other benefits have jointly underpinned the remarkable popularity of the car, and its current dominance of urban transport systems in many cities in the world.

However, recent surveys suggest that the love affair with the car may be ending in countries such as Australia, the United States, and Europe, where cars are now so commonplace that they have lost much of their former mystique.

A recent survey conducted in Australia found, for example, that very few people associate cars with status or sex appeal and that most are concerned with reliability and other more "mundane" qualities.

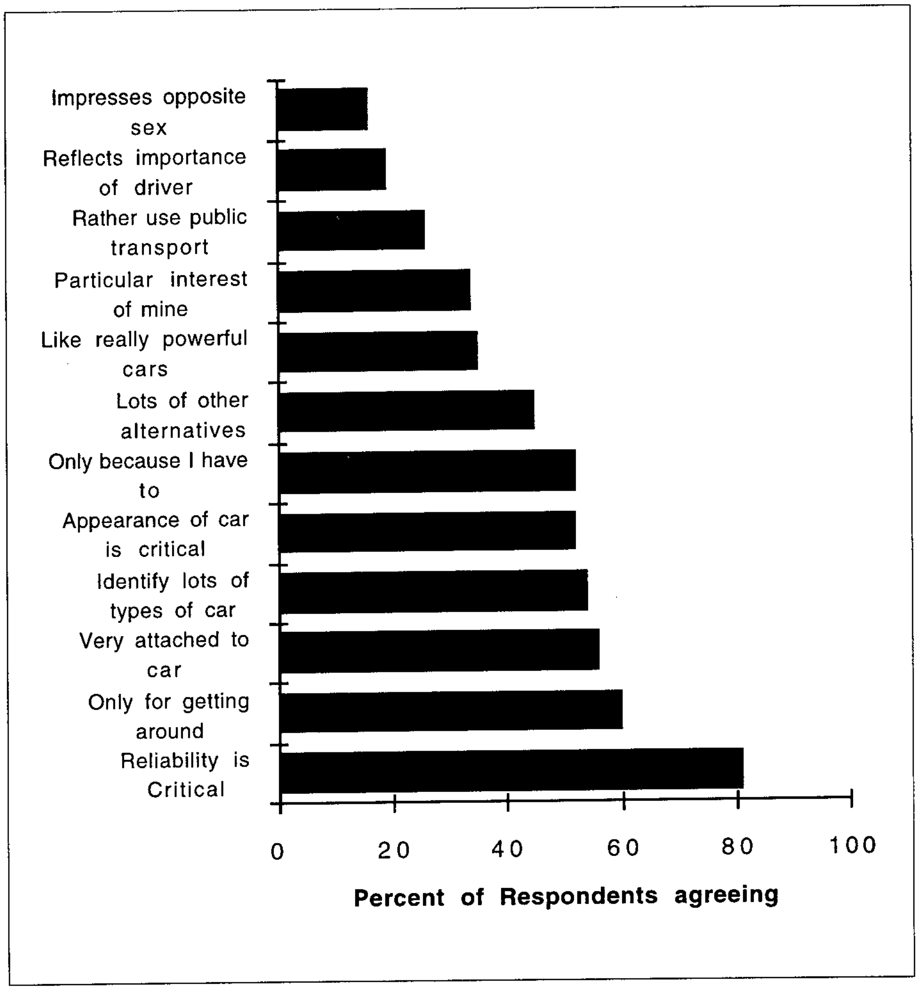


Figure 1. Attitudes to the car: survey of Australian motorists, 1996

For example, only 15 percent thought cars impressed the opposite sex, while 55 percent used cars only because they had to.

While the extent of the private benefits from cars may be leveling out in western countries, the concern about the public costs of car dependence continues to grow in both developed and developing countries. For example, recent

Transport studies for Sydney (Australia's largest city) and South East Queensland (the fastest growing region) found that, given current trends, air pollution accidents are likely to increase rapidly, while congestion and traveling times were also likely to increase dramatically.

Table 1
Public Costs from Private Cars: Current Trends in Sydney and South East Queensland

Sydney		*South East Queensland*	
Characteristic	*% Increase 1991-2016*	*Characteristic*	*% Increase 1991-2011*
CO_2 Emissions	22	CO Emissions	51
Air Quality Decline	36	HC Emissions	27
Fuel Consumption	23	NO_x Emissions	99
Accident Costs	66	Accident Costs	82

Source: NSW Government (1992); Queensland Government (1996).

Public transport, on the other hand, can be characterized as offering low private mobility benefits but at a lower overall social cost in terms of pollution, congestion, accidents, land requirements, and environmental impact generally.

From the perspective of the public, recent research in Sydney illustrates some of the features desired in a public transport system and the level of satisfaction with current train, bus and taxi services. Sydney has a population of 3.8 million housed mainly in low density suburbs and has Australia's most extensive and heavily-used public transport system, including:

- a large suburban rail system including 275 stations and 1,500 double-deck rail cars,
- a large network of bus services provided by both public and private bus operators, incorporating over 3,000 buses,

- some 4,300 taxis, now mostly computer dispatched, and
- an extensive ferry service on the Harbour and Parramatta River.

The results are based on a sample of 300 residents (Douehi 1996) in a typical inner suburb (Leichhardt) and typical outer suburb (Fairfield) of Sydney. The sample covers a wide range of incomes, household types, and lifestyles, ranging from double-income, professional couples with no children (DINKS) to the typical nuclear family, and can therefore be considered broadly representative of attitudes in the larger Australian cities (see Figures 2 and 3).

Research in Perth (Reark and Associates, 1995) and other cities has revealed similar conclusions that current public transport services in Australia are not fully meeting people's needs. In particular:

- Train services are not considered safe, particularly at night and weekends. This is a particular concern among women.
- Bus services are generally inadequate in terms of frequency and reliability and also do not provide for cross-suburban linkages. People also complain of lack of information about arrival times at stops.
- Taxis, while generally convenient (except at times of peak demand), are too expensive for most people to use on a regular basis.

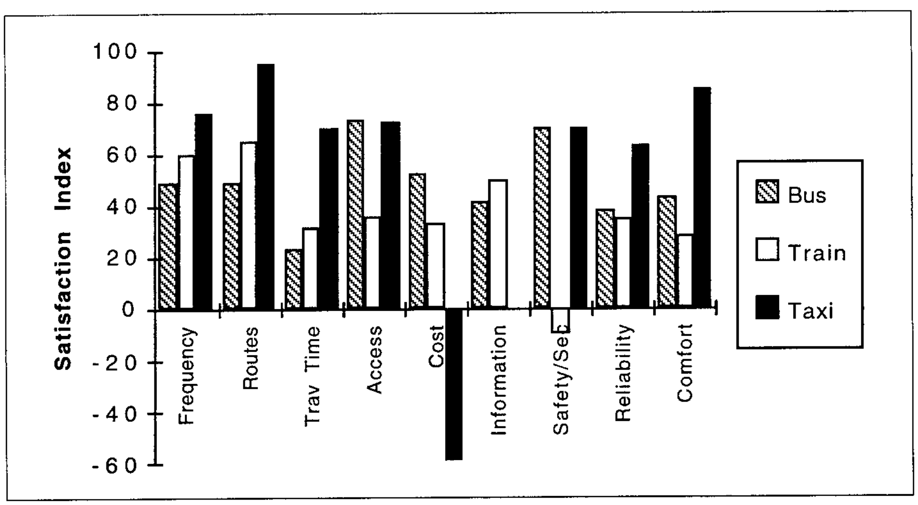


Figure 2. Satisfaction by mode and characteristic (Sydney).

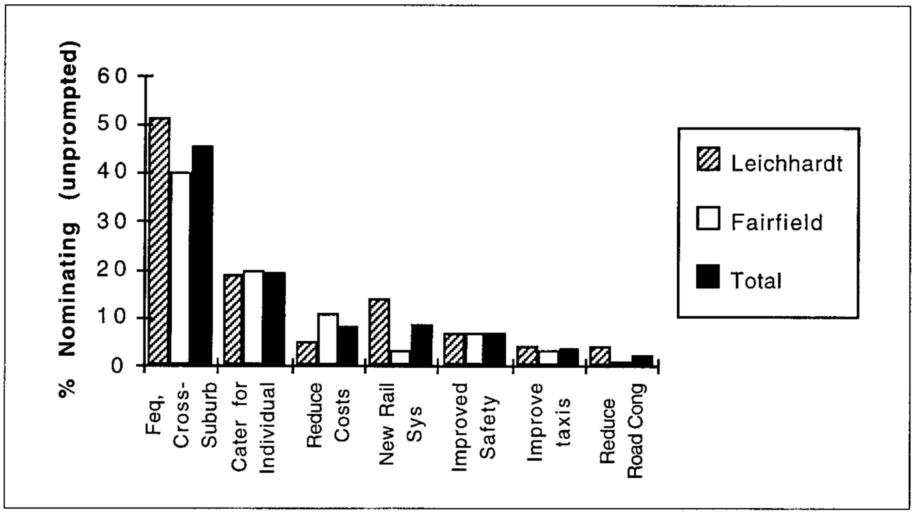


Figure 3. Desired improvements to public transport.

New Solutions to Urban Transport Needs

Urban transport planners thus face a challenge: how to provide a better overall balance between private benefits and public costs of travel. The ideal transport system would combine low public costs with high private mobility benefits. Unfortunately, we are currently constrained to trading off between public and private modes, both of which have undesirable features. This trade-off fails to move us towards the ideal transport system.

New solutions are needed that can:

- reduce the public costs of private travel, and
- increase the private mobility benefits of public transport.

Such strategies could greatly increase the range of choice available in overall transport terms and move us towards a more ideal system.

Developments in Urban Public Transport

The Personal Public Transport Concept

Personal Public Transport (PPT) is a new approach to public transport involving:

- the introduction of *new multi-hire, on-demand services* provided by maxitaxis and taxibuses, with a fare structure between that of taxis and scheduled bus services; these new modes would be computer dispatched using the latest multi-hire dispatching software systems;
- the linking of all modes (trains, buses and other scheduled services, and single and multi-hire, on-demand services as well as car and van pooling) into a *seamless integrated multimodal system* by connecting all vehicle fleets to one or more control centers in real time;
- the *provision of real-time information and booking services* to individuals by a range of communication channels, including current telephone networks, the internet, and networks of electronic bus stops or kiosks, closely spaced throughout the urban area; and
- the use of contactless smart cards and customer accounts to provide an *integrated fare collection and distribution* system, which will eventually dispense with the need for cash-based ticketing systems.

The benefits from introduction of a full PPT system include:

- ***Increased choice and affordability***—The need for this is illustrated in Figure 4, which shows the current limited range of choices available (with taxi fares typically four or more times more expensive than bus or rail fares for a typical urban trip), together with the new maxitaxi and taxibus fares (expected to be in the order of 70 percent and 55 percent of taxi fares, respectively).

Thus, the new modes will allow customers a meaningful range of traveling options in terms of fares and levels of service. In particular, on-demand, anywhere-to-anywhere services will be available at around half the fare of current taxis.

- ***Increased convenience***—PPT will increase convenience by:
  - allowing people to become account customers of the public transport system, paying all fares by smart card or by account and receiving periodic accounts as happens for electricity, gas or telephone customers;

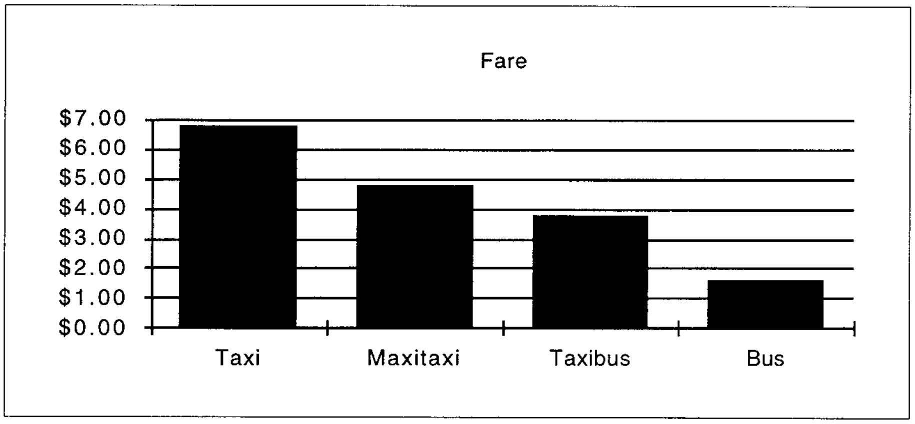


Figure 4. Increasing the range of choice in fare structures.

- providing real-time arrival information of buses at all bus stops—this will overcome one of the key disadvantages of the bus systems in the eyes of the public; and
- making information on all modes available through the one system so that people can make an effective choice between modes or make a journey involving more than one mode. In particular, the network of electronic bus stops will effectively integrate scheduled and on-demand services in space and time. Research in Perth and Sydney, for example, showed that less than 5 percent of bus stops were located close to public telephones and vice versa; this means that a person currently has to choose whether to wait at a bus stop (with no reliable information as to whether they've just missed the bus or if another one is coming), or walk down the street (and risk missing the bus) to find a pay phone to call a taxi.

- ***Increased safety and security***—The use of computer dispatching, booking systems, and AVI systems means that people will be able to book connecting maxitaxi or taxibus services while on a train or express bus, to take them the last few kilometers home or from home to the station or bus. This will reduce the need to wait for an uncertain bus connection and increase the feeling of security in traveling by train in particular. Trips booked on the system will also be logged on computer, providing increased security for both passenger and driver.

- ***Increased efficiency***—PPT will improve the efficiency of existing public transport services:
    - Rail and express bus systems will be able to utilize PPT to widen the catchment areas of their stations, improving overall patronage.
    - Bus operators will benefit from the provision of real-time arrival data at all bus stops and will be able to rationalize their operations by using taxibuses for the lower density traffic and focusing scheduled services on routes with sufficient patronage.
    - Taxi operators will be able to provide maxitaxi services using 6-12 seat vehicles and their current booking systems, thus extending their market and better matching surges in demand (e.g., on Friday nights or after rain) through shifting some of the 4-6 seat vehicles between single and multiple hire modes.

In addition, a proportion of vehicles and drivers will be able to switch between courier (parcel express) services and multi-hire passenger services depending on the time of day and business, thus making more efficient use of vehicles, drivers and control systems.

Feasibility Studies

A number of pre-feasibility and feasibility studies into PPT have now been carried out in Australia, in Perth, Canberra, and Sydney (see, for example, Glazebrook 1995; Glazebrook, Middleton, and Ratcliffe 1994). Key conclusions of these studies include the following.

Technology

The technology needed for establishing a PPT system includes:

- AVI systems (e.g., GPS-based systems)
- multi-hire dispatch software systems
- automatic booking and inquiry systems
- inexpensive PPT stop facilities or kiosks
- mobile data terminals and radio equipment on vehicles

All of these systems are now in use in Australia and in many other countries. The remaining requirement is to complete a fully-integrated system, including the integration of existing modes and operators and the provision of new modes, together with an extensive system of PPT stops to make automatic bookings simple and convenient.

Market Demand

There is likely to be a significant new demand for public transport if a PPT system were introduced, even in areas with high current car ownership (see below).

Performance of the Vehicle Fleets

Simulation studies undertaken by CSIRO using the Litres Model (Rawling, Smith and Davidson, 1995) indicates that multi-hiring can produce efficiency gains (measured by effective passenger-km per driver/vehicle hour) of 60-100 percent, compared with single-hire taxis. This should enable realistic unsubsidized fares of 65-75 percent of taxi fares for maxitaxi services and 50-60 percent for taxibus services. However, multi-hire, on-demand services on an anywhere-anywhere basis cannot be provided at current bus fares (which are typically 20-30 percent of taxi fares in Australia).

The simulations also showed that with realistic vehicle numbers (matching the anticipated demand), average wait times would be:

- approximately 5.5 minutes for taxis
- approximately 7 minutes for maxitaxis
- approximately 10 minutes for taxibuses

These were considered acceptable by the public, as were the average speeds and deviations for multi-hire services (deviations averaged 20-25 percent from shortest route and were controlled below 30 percent for maxitaxis, and 60 percent for taxibuses by the computer dispatching system).

Financial Feasibility

Overall, the cost of establishing a suitable pilot in Australian conditions should be approximately \$8-10m (US \$6.2-\$8m) for the electronic bus stop network (300-500 stops), together with on-vehicle equipment and control center. Additional costs would be required for covering possible demand shortfalls during the start-up phase. It is assumed that the operators would provide their own vehicle fleets. The financial feasibility suggested that a PPT system could be established to run with no ongoing subsidies other than any specific user-side subsidies (e.g., for pensioners or school children), although it would be preferable to launch a pilot project in an area with sufficient trip density and expand from there.

Institutional Issues

There are a number of ways in which PPT could be introduced, ranging from a fully publicly-owned-and-run system to a fully privately-owned system. One option would be for the establishment of a joint venture company to own and operate the control center and network of communication systems (e.g., PPT stops), with that company contracting with bus and taxi operators to provide certain numbers of vehicles and drivers for multi-hire operations as well as real-time data on all their operations. Local government could play a key role in brokering a deal between the various parties and, indeed, in helping to cover the cost of some of the in-ground facilities (in much the same way it funds traffic management and local road infrastructure).

Market Research

A number of market research studies have also been undertaken into the public reaction to the PPT concept in Australia (Douehi 1997; Reark and Associates 1995). These indicate that:

- The public react favorably to the PPT concept, in particular to:
  - its flexibility and ability to match their individual travel needs,
  - the proposed payment systems (accounts and smart cards),
  - the provision of real-time travel information at bus stops,
  - the ability to link on-demand and rail services, and
  - the ability to provide for cross-suburban, shopping, recreational and other trips for which conventional public transport (trains and buses) are not always suitable.

- PPT on-demand modes are likely to be used more for non-work trips (where they could capture a mode share of around 8-12 percent) than for work trips (where they might only account for 2-3 percent).
- On the fare structures likely to prove realistic (see above), the share of total on-demand travel is likely to be approximately 20 percent taxi, 40 percent maxitaxi, and 40 percent taxibus.
- PPT could reduce the need for a second car (and, in some cases, for a first car).
- PPT was particularly well-received by older people, women, and teenagers (whose travel needs are not always well catered for at present) and was more likely to be used by white collar than blue collar workers.

Implications of Introducing PPT

The introduction of new, continuous, multi-hire systems (maxitaxis and taxibuses) would have substantial benefits to the public, particularly for cross suburban trips for which current public transport alternatives are not always convenient.

For example, research into travel patterns in South East Queensland (SEQ, Australia's fastest-growing urban area) reveals that:

- Only 10 percent of motorized trips in SEQ are to or from the Central Business District (CBD); 10 percent are to or from other centers; and 80 percent of trips are "anywhere-anywhere."
- Public transport has a current market share of 22 percent for CBD-oriented trips, but only 4 percent of trips to other centers or anywhere-anywhere trips.
- The average car-based trip is around 5 km.
- A typical 5 km non-CBD-bound trip in the inner suburbs of Brisbane (the capital of Queensland and largest city in South-East Queensland) takes 50 minutes by public transport (including walking, waiting, transfer and in-vehicle time) and costs $2.25, while the taxi alternative takes 16 minutes (including waiting) but costs $8.50. These are currently the only non-car alternatives (see Table 2).

Table 2
Analysis of Typical Inner-Suburb Cross-Suburban Trips in Brisbane

Typical Trip	*Case 1*	*Case 2*	*Case 3*	*Case 4*	*Case 5*	*Case 6*	*Avg*
Crow-Flies Distance (km)	3.63	2.75	5.75	3.75	5.75	5.50	4.52
Total Times:							
Public Transport	55.2	55.0	49.0	48.2	50.5	43.5	50.2
Taxi	12.0	21.0	15.0	12.0	16.0	18.0	15.7
Fares:							
Public Transport	\$1.40	\$3.00	\$2.80	\$2.00	\$1.70	\$2.60	\$2.25
Taxi	\$6.50	\$12.10	\$8.00	\$6.40	\$8.10	\$9.75	\$8.48

By using a mixture of taxis and regular public transport, passengers could, in effect, have other alternatives (e.g., a mode half way between taxi and public transport).

However, maxitaxis and taxibuses could significantly improve the range and cost-effectiveness of the current options. For example, on an average basis, they could reduce the cost of a typical cross-suburban trip (for a given time budget) by 17-27 percent, or the time required for a given cost by 20-25 percent (see Table 3 and Figure 5).

Prospects

Implementing PPT

The biggest difficulty in introducing a full PPT system is the need to integrate all operators in real time and to get cooperation of both bus and taxi industries, which are traditional rivals. The situation is further complicated in Australia by the current franchising-out process involving the breakup of previous government-run monopoly bus services, a process which is occurring in Melbourne, Adelaide, and Perth at present.

Table 3
Estimated Travel Times and Fares for New On-Demand Modes

Typical Trip	*Case 1*	*Case 2*	*Case 3*	*Case 4*	*Case 5*	*Case 6*	*Avg*
Total Times:							
Maxitaxi	21.0	32.3	24.8	21.0	26.0	28.5	25.6
Taxi Bus	24.9	37.5	29.1	24.9	30.5	33.3	30.0
Fares:							
Maxitaxi	$4.23	$7.87	$5.20	$4.16	$5.27	$6.34	$5.51
Taxi Bus	$3.25	$6.05	$4.00	$3.20	$4.05	$4.88	$4.24

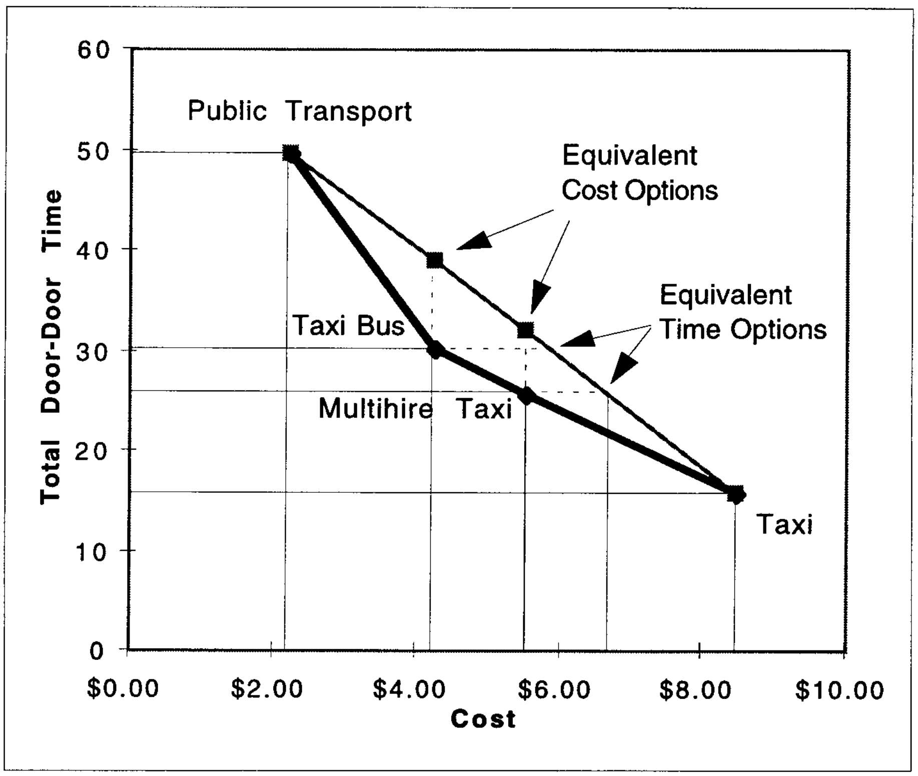


Figure 5. Time-cost tradeoffs—current and future.
Typical 5km cross-suburb trip in Brisbane.

Accordingly, in 1995 the Federal Government, under its Greenhouse 21C program, established an Innovative Urban Public Transport Program to help encourage the establishment of projects such as PPT. Calls for expressions of interest in a national PPT project were made in December 1995, and positive responses were put forward in January by:

- Western Australia (2 submissions),
- the Australian Capital Territory,
- the South Australian Government, in conjunction with Local Government and others, and
- six Local Government Authorities in NSW.

Unfortunately, following a change of National Government in the March 1996 election, the program was discontinued before any funds were allocated.

Prospects in Australia

Accordingly, no complete PPT system has yet been developed or installed in Australia. However, various projects or initiatives are under way that include particular components of an ultimate PPT system. For example:

- In Perth, a Central Area Transit System (CATS) has commenced, featuring new low-floor midi-buses and the use of real-time arrival time information at specially-equipped bus stops in the CBD. This system uses GPS satellite technology to track the vehicles and a computer system to estimate the arrival of the buses at the next stop.
- In Brisbane, the Brisbane City Council is installing transponders on more than180 buses to enable them to trigger bus priority at traffic lights on Waterworks Road and to provide location information for real-time arrival time data at selected bus stops.
- Also in Brisbane, the State Department of Transport launched its Integrated Regional Transport Plan for South East Queensland a few months ago. Among other initiatives, this includes major plans for a busway network and plans for developing an integrated multimodal approach to public transport incorporating Personal Public Transport.

- In Canberra, Action Buses is to sell its existing fleet and lease them back. This will allow them to introduce minibuses into the fleet. There are also plans for running on-demand services.
- Many Local Councils in the Sydney area are taking steps to encourage improved or innovative public transport; for example:
  - Leichhardt Council has included contributions for public transport in its latest draft Section 94 plan, while Leichhardt and Fairfield Councils have funded market research into the adequacy of current services and the ways in which this could be improved.
  - Willoughby and other councils are installing parking meters and plan to use some of the revenue for improving public transport.
  - Councils such as Manly and Sutherland have been arguing for improved services in their areas.
- The taxi industry is continuing to install GPS satellite receivers in its fleets—many fleets are now fitted. To date, this has been used mainly to provide an emergency location system to improve driver safety, but some companies are experimenting with using the location information to track vehicles on a regular basis to aid in dispatching the nearest available taxi, thus improving customer service and fleet utilization. Many taxi operators are also diversifying their fleets; in Queensland, already 10 percent of the vehicles are multi-purpose (5-12 seaters), providing a basis for introducing multi-hire services in the future.
- Adelaide has recently decided to proceed with the MultifunctionPolis project in the northern suburbs. Provision of innovative public transport is likely to be part of this project.
- There are currently several smart card trials under way in Australia, including contactless smart card trials in Western Sydney involving local taxi, bus, and rail operators as well as banks and retail outlets.
- An Australian company, Dynamic Transport Management, has developed one of the world's most advanced dispatching systems for the courier industry capable of handling multi-hire dispatching applications for

passengers. Virtually all of Australia's taxi industry is now computer dispatched using advanced single-hire dispatching systems, mostly using Raywood equipment. This expertise has already led to export opportunities for both of these companies in the Asia-Pacific region, the United States, Europe, and the Middle East.

Table 4 summarizes some of these developments.

Hence, it is hoped that further developments will enable an integrated approach to be developed that incorporates the full PPT concept with new multi-hire modes, extensive network of PPT stops, and integration of scheduled and on-demand services in real time.

PPT and PRT—A Comparison

Capital and Operating Costs of Personal Public Transport

PPT is essentially an approach based on utilizing current public transport vehicles and adding Intelligent Transport Systems to provide new types of services and to integrate all services in real time into a seamless system from the perspective of the customer.

As such, it is a relatively low capital cost system, with the main expenditure being on communications systems. The on-demand vehicle fleets would be expanded considerably, but these are relatively cheap. No new roads would be required. The total capital cost for a PPT system for a city the size of Sydney (population 3.8 million) and capable of handling at least 5 percent of total motorized trips in the metropolitan area, is estimated in Table 5.

Thus, total capital expenditure for Sydney would be expected to be of the order of A$1 billion (US $800 million), which would probably be spread over a decade or so. This compares with annual capital expenditure of A$600 million on the CityRail network, and more than that on major roadworks in Sydney. For example, the following are some of the major projects recently completed or under way at present in Sydney:

- the New Southern Railway (A$670 million) (under construction)
- the Homebush Bay Rail Line (A$70 million) (under construction)

Table 4
Current Trials and Initiatives in Australia

Location Initiative	*Sydney*	*Melbourne*	*Brisbane*	*Perth*	*Adelaide*	*Canberra*
Integrated (non-real time) pass Info System	Yes		Yes	Yes		
Computer dispatching of taxis	Yes	Yes	Yes	Yes	Yes	Yes
GPS on taxis	Yes	Yes	Yes	Yes		
GPS/AVI on buses	Small trial		180 buses	15 spec. buses		
Real-time arrival information	Some stations and sev. bus stops	Some stations and on trial for trams	Select bus stops on trial	Spec. stops in CBD		
Use of "maxi-taxis" by taxi industry	Limited		Extensive			
Use of mini and midi buses	Extensive	Extensive	Limited			Com-mencing
Franchising of bus services	Yes	Extensive		Under way	Under way	
Smart card trial	Yes					
Information kiosk trial					Yes	Yes

- the Ultimo Pyrmont Light Rail Line ($A60 million) (almost completed)
- the Eastern Distributor (A$600 million) (about to commence)
- the M5 Motorway (A$650 million) (just completed)
- the Harbour Tunnel (A$700 million) (completed)

Table 5
Estimated Capital Cost for a PPT System for Metropolitan Sydney

Item	*No. Required*	*Cost per Item A$*	*Total Cost A$m*	*Cost per Capita A$*
Control Centers				
Regional	10	6m	60	16
Main Center	1	20m	20	5
Subtotal	11		80	21
Additional Vehicles				
Maxitaxis	6,000	50,000	300	80
Taxi buses	4,000	100,000	400	105
Subtotal	10,000		700	185
Mobile Equipment				
Taxis	4,300	2,000	9	2
Maxitaxis	6,000	3,500	21	6
Taxi buses	4,000	3,500	14	4
Subtotal	14,300		44	12
Electronic Bus Stops	21,000	12,000	250	66
Total			1,074	282

While the capital costs for a PPT system would be low, the operating costs for the on-demand components would be relatively high due to the need for drivers and the use of small vehicles. This is reflected in the anticipated fare structures, which are expected to average around $1.00 per kilometer for a 4 km trip for the multi-hire on-demand modes (compared to an average of 50-80 cents per kilometer for the full cost of driving, excluding parking and externality costs—congestion, pollution, etc.).

The figure expected in other cities would depend on factors such as population density, wage structures, ownership models assumed for the on-demand fleets, road congestion levels, etc.

In higher-density cities, such as are typical in Europe or Asia, average seat occupancies will be higher, although this will be counterbalanced by lower average travel speeds. Low-density cities such as those found in the U.S. will generally have longer trips, higher speeds and somewhat lower occupancy factors.

Capital and Operating Costs of Personal Rapid Transport

Personal Rapid Transport is a generic name for systems combining the use of small vehicles (to provide flexible and personalized transport) with guideway and control systems to allow those vehicles to move without drivers.

Generally, such systems can be expected to exhibit (relatively) high capital costs, particularly if grade separation from existing streets and pedestrians is required, but low operating costs (due to the automatic control systems). For example, Table 6 compares capital costs for PPT and some PRT systems examined in relation to the Gold Coast in Queensland.

The particular cost structures will depend on the particular city or application concerned, and the details of the particular system adopted.

Table 7 summarizes some of the main features of PRT vs. PPT.

Table 6
Comparison of Capital Costs: PPT vs. PRT

	PPT (a)	*PRT (b)*	*PRT (c)*
Total Capital Cost	A \$90 m	A \$140 m	A \$240 m
Estimated Ridership	16 million	16 million	20 million
Capital Cost/Rider	A \$6	A \$9	A \$12

Sources:
(a) Author's estimate; assumes full PPT multihire system capturing 4-5% of motorized trips in Gold Coast area. Includes cost of vehicle fleets required.
(b) Austrans System (based on estimates provided by Austrans); captures high percentage of line-haul trips in densely used coastal strip.
(c) Overhead Suspended PRT System evaluated for Gold Coast; captures high percentage of line-haul trips in densely used coastal strip.

Table 7
Comparison between Key Characteristics of PRT and PPT

Characteristic	*PRT*	*PPT*
Capital Cost	High	Low
Operating Cost	Low-Medium	High (On-demand modes)
Potential Suitability for:		
• Specialist applications (e.g., airports)	High	Med
• Downtown distributors	High	Med
• High volume links	Med	Med-Low (on-demand modes)
• Purpose-built new town developments	Med	Med
• General suburban areas	Low	High
Ease of retrofitting into existing urban environments	Low	High

This suggests that PRT systems are likely to first be established in specialized areas (such as links between airport terminals and surrounding car park areas, new town developments, or resort areas), while PPT could be installed virtually anywhere. In both cases, however, initial resistance is likely from current transport operators unless they can be incorporated into the solution (this is much more likely with PPT than automated systems such as PRT).

PRT systems are also likely to be more suitable in high income communities where wage rates are high and, hence, competing transport systems are expensive, or where congestion is so bad that politicians are forced to undertake major investments to solve the problems.

Evolution of our Cities—A Simplified Paradigm

Where do PPT and PRT fit into the bigger picture?

In very simplified terms, our society can be seen as evolving through various stages over the last few centuries, from the pre-industrial through the industrial and post-industrial ages to the future "communitarian" age.

As discussed by Lepani et al. (1995), this process of evolution has economic, social/psychological, and physical (including urban structure and transport systems) dimensions; it also reflects a general principle of nature for increasing overall structural complexity, as illustrated below.

Our urban structures have been transformed from villages and small towns, to the high-density but structured cities of the industrial age, then to the sprawling suburban regions of today. This process is still continuing in countries such as China, India, and Indonesia, where rural-urban migration continues at a high rate.

In urban transport terms, we have seen first the rise of mass public transport systems (predominantly heavy rail and electric tram) in the industrial age, followed by the rise of mass private transport in the form of the car in the post-industrial age.

The social parallel was the demise of the local community and the rise of mass movements, class structures, and nationalism in the industrial age, followed by the rise of the cult of the individual. In psychological terms, the industrial age was characterized by conformity; the post-industrial age was characterized by freedom and its resultant chaos.

The costs of the current post-industrial age in social, environmental, and psychological terms are beginning to be understood more widely. As this happens, future societies will begin to emerge. These are likely to be based on new value systems in which environmental and social awareness is more apparent than it is today, with correspondingly less emphasis on individual consumption. There is likely to be both increasing global connectivity at one level, and increasing local connectivity at another, with a renewed focus on belonging. However, unlike previous village societies, people will have greater flexibility to choose

Table 8
Economic, Social/Psychological, and Physical Evolution: A Simplified Model

Stage of Evolution Dimension	*Pre-Industrial*	*Industrial*	*Post-Industrial*	*Future Communitarian*
Economic	Feudal; limited trade; small-scale production;	Nation states; global trade; economies of scale; producer economics	Borderless world; economies of scope; consumer economics	Integrated world; economics and ecology; quality of life economics
Social/ Psychological	Highly-structured but inward looking; religious view	Class-structured; but increasingly open	Individualistic; high levels of mobility and stress	Reconnected societies with greater emphasis on localism and belonging
Urban Structure	Villages and small towns	Major industrial cities	Metropolitan regions	Urban village networks
Urban Transport	Walk, horse-drawn vehicles	Mass transit	Automobile	PPT, PRT
Physical Analogy	Solid	Liquid	Gas	Organic molecure
Energy Use	Low	Medium	High	Medium
Entropy (Disorder)	Low	Medium	High	Medium
Intercon-nectedness	Low	Medium	Medium	High
Overall Structural Complexity	Low	Medium	Medium	High

among a range of communities, with distinct but more sustainable lifestyles, technologies and value systems.

If this broad thesis is accepted, then it is likely that new urban transport systems that provide a better overall balance between individual mobility and environmental and community welfare will emerge. PPT and PRT are likely to be strong contenders for such systems. ❖

References

Douehi. 1997. An Analysis of Public Transport Utility and Feasibility of Personal Public Transport in Leichhardt and Fairfield. Reports produced for Leichhardt and Fairfield Councils.

Glazebrook and Associates. 1995. Personal Public Transport for Canberra. Pre-Feasibility Report. Report prepared for the ACT Department of Urban Services, March.

Glazebrook, G., A. Middleton, and M. Ratcliffe. 1994. Personal Public Transport for Perth. *Proceedings of the First World Congress on Intelligent Transport Systems.* Paris, December: 3032-3039.

Glazebrook, G. 1996. Oz public transport goes personal. *ITS International.* Issue No 4, London, March: 94-95.

Lepani, B., et al. 1995. The Ryde Urban Villages Study. Report prepared for Ryde City Council (Sydney).

NSW Government. 1992. Future Directions Study for Sydney. Report prepared for NSW Roads and Traffic Authority.

Queensland Government. 1996. Integrated Regional Transport Plan for South East Queensland. Draft Discussion Report.

Rawling, M., J. Smith, and I. Davidson. 1995. Modelling of Personal Public Transport in a Multi-Mode Service Environment. *Proceedings* from the International Conference on Application of New Technology to Transport Systems. Melbourne, Australia. May: 167-178.

Reark and Associates. 1995. Personal Public Transport for Perth: Market Research. Report prepared for WA Department of Transport, East Perth Redevelopment Authority and Telecom Australia.

About the Authors

GARRY GLAZEBROOK is an Associate with Booz-Allen & Hamilton (Aust) Limited in Sydney, Australia.

SAM SUBRAMANIAM is an Associate with Booz-Allen & Hamilton Limited in McLean, Virginia.

The Characteristics of Shopping Trips by Bus Transit

Salameh A. Nsour
Santa Clara University

Abstract

This paper presents a summary of the findings of a one-year research project that was sponsored by the Federal Transit Administration (FTA) and conducted on the characteristics of shopping trips using bus transit. The study involved the collection of extensive amounts of data on shopping trips and on the shoppers themselves in a large sampling area in California. It describes the integrated environment a shopper faces starting from his or her home and ending at the entrance of a mall. This includes analyzing the distances from home to bus stops, travel time on the bus, frequency of transfers, and the walking environment from bus stops to mall entrances. Also characterized are the distributions of shoppers and bus users on the basis of gender and age and the implications of these distributions in regard to what should be improved in bus service. Several other attributes of shoppers and shopping trips were collected, analyzed, and included in the recommendations. A total of 45 malls, 22 transit authorities and more than 1,000 shoppers were surveyed through relatively lengthy questionnaires for their opinions and for data on a wide range of issues. The most important finding of this work is that no organized or significant efforts exist between mall operators and transit authorities, to continuously monitor and improve shopping by bus, especially in regard to the location of bus stops around malls and the safety and

convenience of the walking environment for a shopper who uses the bus and walks to and from the mall entrance.

Introduction

This research project examined the main components and phases encountered in the process of shopping by bus in order to identify problems that could be eliminated partially or completely so that the environment of shopping by bus would keep its current users and attract more users. The study explored the views of the basic partners of this process, namely, transit authorities, shopping center operators, and shoppers themselves. The methodology of this research relied heavily on collecting, examining, and analyzing the thoughts, opinions, and data provided by various parties who answered surveys and questionnaires. Moreover, on-board observation was also employed to get first-hand insight of shopping by bus. Site investigation of 10 malls was conducted to study the conditions and characteristics of the paths that shoppers follow from bus stops to the mall entrances. Selected areas in the cities of Fremont and San Jose, California, were analyzed regarding bus service and the spatial relationships of residential areas to shopping areas. The routes, transfers, and travel times involved in the process of shopping by bus were also analyzed in the sample areas. The study involved questionnaires sent to 220 shopping centers in various states, 45 of which responded. The content of these questionnaires is described in the next section, "Survey of Malls." Also, 22 transit authorities operating bus services in California urban areas, having a total population of more than 18 million, answered and returned questionnaires. The results can be classified as follows in accordance with the major survey or substudy performed in connection with the area under consideration.

Walking Environment from Bus Stops to Mall Entrances

To examine the issues involved in the bus-stop-to-mall environment, the walking paths from bus stops to 10 randomly-selected malls in the San Francisco Bay Area of California were surveyed, and field measurements were taken of parking lots, walkways, sidewalks, and the relative locations of bus stops near each mall. Besides "as built" field measurements, original plans were checked whenever possible. Observations were made to verify and track all of the different paths taken by shoppers coming from or going to bus stops from various points or entrances of a mall. The main findings in this respect are described in the following section.

The average ratio of walking distances on a sidewalk to the total distance of 40 paths (from bus stops to mall entrances) is about 50 percent, reflecting a relatively high amount of walking over stretches without any sidewalks. The total walking distance for these paths ranges from 20 to 3,245 feet. According to the findings gathered by direct questionnaire from a sample of 1,068 bus users,

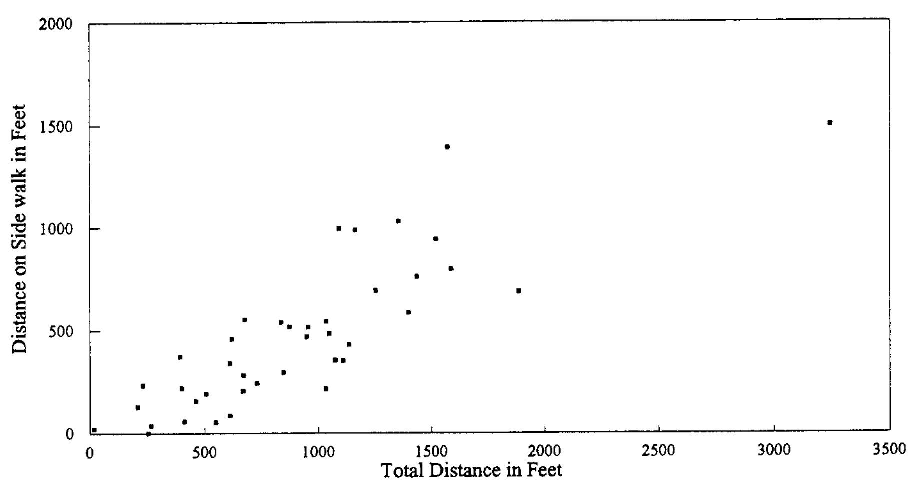


Figure 1. Relationship of total distance to sidewalk length.

the average walking distance considered acceptable is about 1,190 feet. Figure 1 depicts the individual ratios of length of sidewalks to the total length of the path.

Survey of Malls

There are split opinions regarding the use of a shuttle bus between bus stops and mall entrances. Several issues surfaced in discussing this idea, including legalities, insurance, pavement damage, and schedule information. Regarding improving paths between stops and entrances, it appeared that there is not always clear agreement between mall operators and transit authorities on the responsibilities of providing well-defined, safe, and short walking paths wherever possible. Also, there are no clear-cut guidelines or standards for providing a walking environment.

There are also split opinions about the proposed idea of under-carriage space in buses for storing shoppers' purchases. Some replies from mall administrators indicated unsubstantiated perceptions regarding reasons that some people do not favor using a bus for transportation to shopping such as that most customers are females or that the behavior of some young people on the bus discourages others from using the bus.

Surveys also revealed that most mall operators do not have a realistic idea about the number of shoppers or percentage of people using buses for shopping trips, nor of the extent of bus service to malls. A lack of concern for where the bus stops are located seems to exist among many mall operators and, thus, little is done to make the stops closer to mall entrances or to make the path from bus stops to mall entrances a safer environment.

Some mall operators believe that many young people ride buses to malls but seldom make purchases there. These perceptions might explain the intentional lack of concern towards improving bus stop locations around malls.

It should be pointed out that the term "shopping mall" incorporates both enclosed shopping centers and very large strip shopping centers. This research did not include any data or investigation of whether the owner of the center has a role in setting bus passenger access to given shopping sites or if it is a decision by local managers.

Survey of Transit Authorities

The survey showed that shoppers face many problems with the environment of shopping by bus in various magnitudes. Among these problems are safety, space in bus for placing packages, difficulties in boarding and alighting, schedule problems, and inconvenient bus stop locations around shopping centers. Some communication exists between some shopping center operators and transit operators, while others have no contact or mechanisms to work on any issues related to improving service to shoppers by bus. The main issues noted from the replies of several transit authorities on communication related to access to malls are:

- The communication about and coordination of the bus stop locations between mall operators and transit operators practically ends once the mall starts operating. Very little follow up is done.
- There is great need for formulating a clear concept of convenient bus stop locations and, consequently, the concept of proper paths.
- To achieve better service, coordination is needed related to shuttling shoppers from bus stops to mall entrances and locating convenient stops. For example, in cases where physical or jurisdictional obstacles prevent closer bus stops, both sides can resort to shuttle services.
- Formulating the procedures for contact: times and issues should be streamlined.

It was also noted that not enough surveys and studies are conducted by transit authorities to collect data on various components of shopping by bus. It should be noted, however, that there has been some significant effort by many transit authorities to improve access to malls. This was evident from attempts by authorities to keep bus stops inside shopping mall grounds after being asked by malls to move bus stops outside the grounds. Also, some local jurisdictions have adopted transportation control measures that may aid in getting bus stops closer to malls. On the other hand, some shopping centers welcome bus patrons and even allow a portion of their parking lots to be used for park-and-ride service. Others allow a major time transfer point or even mini-terminal to be located at the mall.

According to information provided by transit authorities, the average number of times per month a person uses the bus for shopping is approximately 10. Trips with one or no transfer may have distances up to 20 miles, but on the average, two-transfer trips range from 4 to 20 miles and three-transfer trips range from 8 to 20 miles. Once a trip exceeds eight miles, it is likely to involve two transfers or more.

Figure 2 shows the distribution of agencies surveyed with respect to the average number of transfers encountered in trips of various lengths in their areas of service.

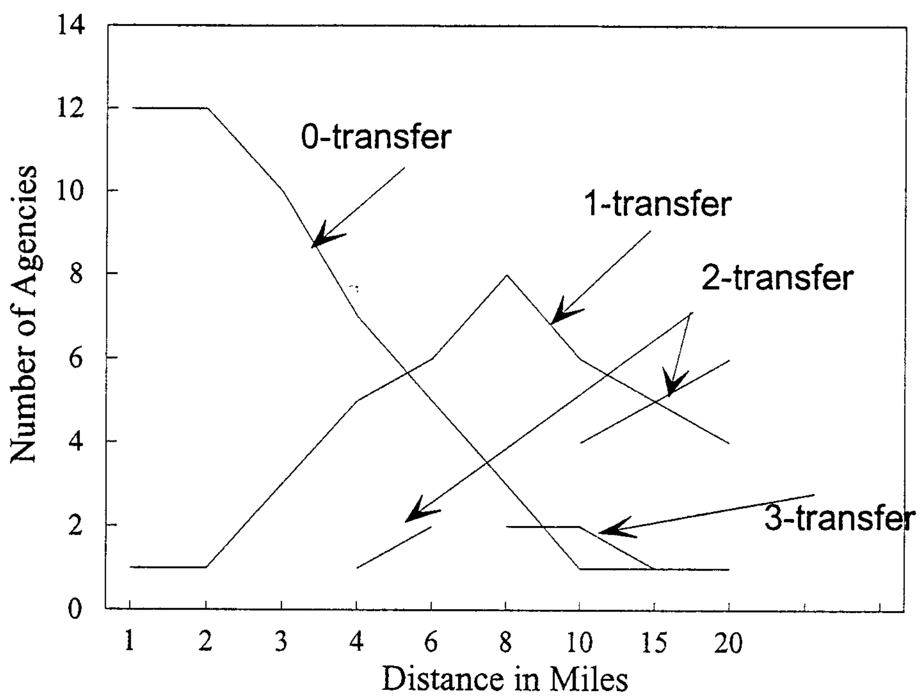


Figure 2. Number of agencies vs. number of transfers for particular distances.

Counts and Observations Performed at Two Malls

After spending several days conducting counts of bus patrons boarding and alighting buses at two malls in the subject areas, the following were found:

- There exists an appreciable portion of shoppers who stop at more than one shopping center using the bus.
- The approximate percentages of people using buses for shopping out of the total number of shoppers for the same malls in the given periods were 3 percent and 1.41 percent, respectively.
- The approximate percentages of people arriving at the two shopping centers by bus and not purchasing anything are about 20 percent and 58 percent.

The wide variations in the above results indicate a strong need for more data on the statistics of these aspects to allow for proper conclusions.

Surveys were done to estimate the percentage of shoppers using the bus vs. those using other means of transportation for shopping at two malls other than the previously-mentioned malls. Based on 1,331 interviews at both malls, 84.4 percent used private autos and 9.5 percent used buses, while 6.1 percent walked or used bicycles.

Also, this survey showed that 45 percent of those using private autos would consider using bus service for shopping under various conditions, such as when a private vehicle is not accessible, in peak traffic conditions, and during periods when parking at the mall is problematic.

Shopper's Gender and Age Surveys

A separate set of surveys was conducted to examine whether appreciable differences exist for the gender and age of shoppers, in general, and of shoppers by bus, in particular. This was to trace any impact such differences might have on using bus service for shopping.

The surveys indicated the following results:

- For shopping in general (the sample included 10,441 people):
  - About 56 percent of shoppers at food stores were female, 52.9 percent at K-Mart, and 74.5 percent at Mervyn's. The total percentage of females for all types of stores is 60.5 percent. Shoppers 25 to 60 years old comprise 63 percent of those who use bus service. About 14 per-

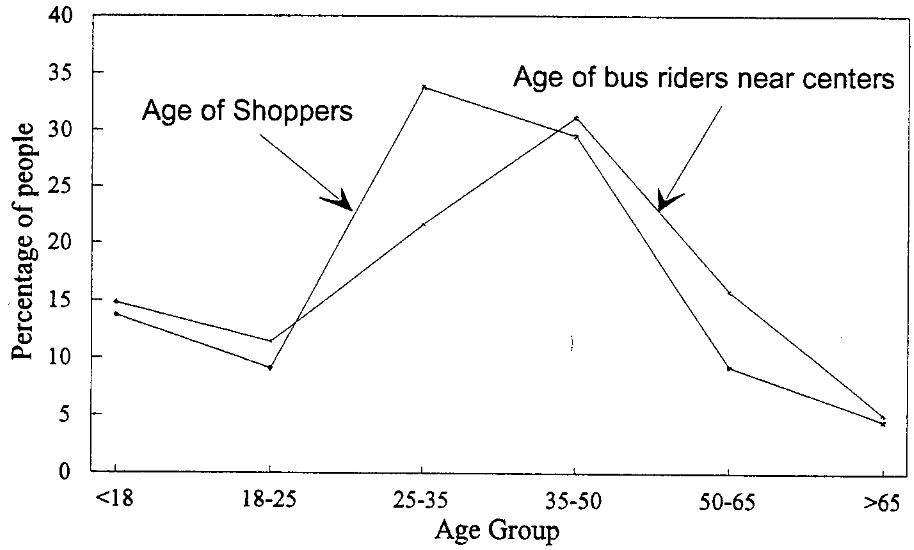


Figure 3. Age distribution of bus riders near stores.

cent of shoppers are less than 18 years old, and at least 22 percent of adults traveled to the malls in groups.

- For those riding the bus near a shopping center (the sample includes 2,309 responses):
  The results of this survey indicated that the percentage of females at food stores is 52.6 percent, which is less than the percentage of females shopping at those stores. This might imply that bus ridership by females is impeded by certain factors or conditions in bus service such as safety. Figure 3 depicts the distribution of ages of shoppers and of bus riders near shopping centers. It shows that the percentage of shoppers is higher than that of bus riders for age groups between 18-25 and 35-50. For other ranges of ages below and above these ranges, the percentage of bus riders is higher.

Direct Interviews of Shoppers Traveling by Bus

A total of 1,068 shoppers who traveled by bus at several malls were interviewed to determine specific aspects of their trips to the shopping centers at which the interviews were conducted. The following results were obtained:

Walking Time from Home to First Bus Stop—The median walking time was 4 to 5 minutes, the mode was 5 minutes, and the weighted mean was about 6 to 8 minutes. A total of 15.9 percent of people had walking times of more than 10 minutes, and 5.4 percent had walking times of more than 20 minutes.

Number of Transfers—One or two transfers were involved in 90 percent of all bus trips; approximately 10 percent had more than two transfers.

Total Travel Time on Bus—The median travel time of the trips was between 15 and 20 minutes, and at least 5.7 percent of the people experienced travel times of more than 45 minutes.

Distance from Home to Shopping Center—The median distance from home to shopping center was about 3.2 miles, and the cumulative percentages of users within 1, 2, and 3 miles was 11.3 percent, 28.5 percent, and 47.7 percent, respectively. The majority of respondents (85.1 percent) came from home origins within 10 miles from shopping centers. Table 1 represents the distribution of shoppers using the bus, based on the distances from home to shopping centers.

Bus Service

At least 40 percent of respondents rated schedules during weekends and holidays as "fair" and space for groceries and safety as "low." About 16 percent rated the information on schedules as "confusing" or "not clear." Table 2 shows the ratings of the various components of bus service by users.

General Aspects of Using a Bus for Shopping

- A total of 28.5 percent stated that there were places for shopping that buses do not serve.
- About 45 percent stated they would buy more things had there been more space on bus for their purchases.

Table 1
Distance Between Home and Shopping Center

Distance in miles	*Number of people*	*Percent*	*Cumulative Percent*
0.5	46	4.5	4.5
1	69	6.8	11.3
1.5	86	8.4	19.7
2	90	8.8	28.5
2.5	93	9.1	37.6
3	103	10.1	47.7
4	109	10.7	58.4
5	183	17.9	76.3
10	90	8.8	85.1
>10	104	10.2	95.3
>5[1]	48	4.7	100.00

[1]This group resulted from people selecting the "more than 5 miles" response in the relatively small pilot survey before the "10 miles" and "more than 10 miles" options were added to the possible responses for this question.

- A total of 71 percent support the idea of having a free shuttle bus between the bus stop and the mall entrance.
- A total of 60 percent made the subject trip for shopping and other purposes.
- The mean number of times of using the bus for shopping per month was 8.7, and 13.5 percent use the bus daily for shopping. Table 3 represents the frequency of using the bus per month. Linear multiple regression analysis showed that no correlation exists between the number of times per month a shopper uses a bus and a set of factors that were speculated to affect such frequency. These factors are: travel time spent on the bus, distance from the center, walking time from home to the bus stop, the

Table 2. Distribution of Ratings of Bus Service

Rating	*Schedule (weekdays)*	*Boarding*	*Seating yourself*	*Alighting*	*Space for groceries*	*Safety on bus*	*Schedule (week-ends/holidays)*	*Safety (both ends)*	*Fare*
Excellent	145 (14%)	162 (16%)	186 (18%)	159 (15%)	105 (10.5%)	149 (15%)	67 (7%)	98 (10%)	75 (8%)
Good	519 (50%)	613 (59%)	606 (59%)	623 (61%)	47 (47%)	507 (50%)	301 (31%)	480 (49%)	392 (40%)
Fair	289 (28%)	232 (23%)	215 (21%)	216 (21%)	345 (34%)	270 (26%)	313 (33%)	337 (34%)	330 (33%)
Poor	82 (8%)	25 (2%)	26 (2%)	26 (2%)	86 (9%)	95 (5%)	279 (29%)	73 (7%)	191 (19%)
Total	1,035	1,032	1,033	1,024	1,008	1,021	960	988	988

average ratings of bus service, and number of transfers. More studies are needed to ensure the generality of this result.

Captive vs. Choice Riders

A total of 19.5 percent of bus users interviewed owned cars but use the bus for shopping in addition to using either their own cars or friends' cars. However, 23.4 percent stated they do not own cars; a relatively high percentage (46 percent) stated that they would still use a bus for shopping even if they owned a car.

The average usage of buses for shopping by "choice" riders is 6.6 times per month, compared to 9.0 for captive riders, indicating a greater potential for more choice riders to use buses for this purpose. However, the average trip length, distance from center, and walking times are almost identical for captive and choice users. The average ratings by choice users of all aspects of bus service are somewhat higher than those by captive users.

Table 3
Frequency of Bus Usage per Month for Shopping

Number of Times/Mo.	*Number of People*	*%*	*Cumulative %*
1	90	8.6	8.6
2	89	8.5	17.1
3	115	11.0	28.1
4	135	12.9	41.0
5	141	13.5	54.4
6	83	7.9	62.4
7	111	10.6	73.0
8	2	0.2	73.2
10	76	7.3	80.4
15	62	5.9	86.3
25	2	0.2	86.5
30	141	13.5	100.0
Total	1,047		

General Characteristics of Shoppers by Bus

- Age: A higher percentage of young people used the bus (80 percent of shoppers are about 35 or younger).
- Amount of purchases: The median amount spent on purchases was about \$26.10. As shown in Figure 4, the percentage of people decreases as the amount of purchase increases. More study is needed on this aspect.

Summary and Conclusions

Based on the surveys, several conclusions can be reached regarding the use of buses by shoppers:

- Shoppers traveling by bus face many problems, most important of which are an excessive numbers of transfers, schedules (especially on weekends), safety, and accessibility from bus stops to shopping centers.

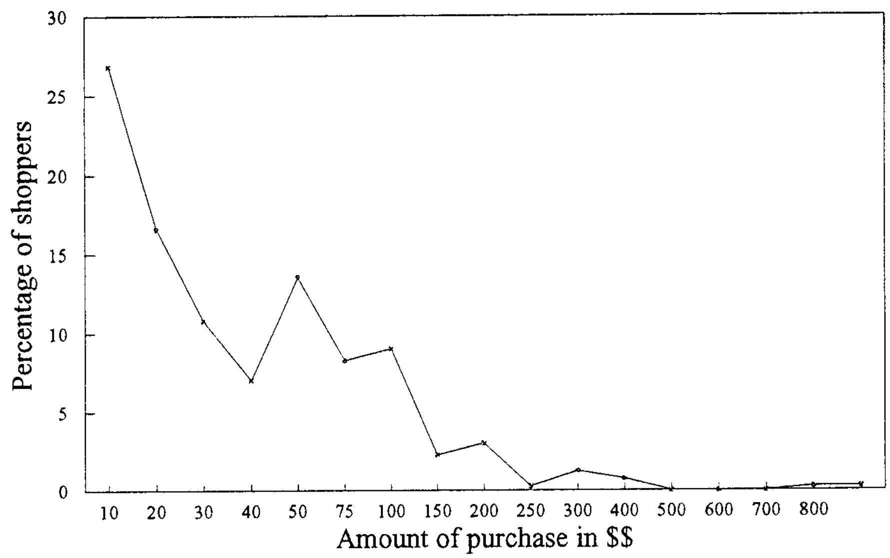


Figure 4. Distribution of value of purchases.

- Extra space on the bus and better seating arrangements would surely encourage shopping by bus.
- It appears that there is not enough coordination and communication among mall operators and transit authorities related to shopping by bus. More coordination is required to streamline efforts, especially in locating bus stops nearby and/or inside mall parking lots, improving walking paths from bus stops to mall entrances, and implementing the service of shuttle buses wherever applicable.
- Characteristics of shoppers using buses such as age, gender, and shopping in groups should be taken into consideration when improving bus service and shopping environment.
- Females constituted a larger percentage of shoppers and showed slightly more concern for safety.

- Very young people make up a sizeable portion of bus shoppers and are often the object of complaints concerning certain behaviors on the bus.

More data and surveys should be available and ready to be analyzed by transit authorities when planning to improve aspects of shopping by bus. Some mall administrators think that the small number of shoppers by bus makes the issue unimportant or insignificant; many who were surveyed had no idea about the estimated segment of shoppers by bus.

Other conclusions and recommendations are:

- There is a need to produce guidelines on the acceptable distances between bus stops and entrances to shopping centers. There is also a need to classify walking paths—whether or not they are on sidewalks—and then to set guidelines on the ranges of acceptable distances that a shopper walks on segments that are *not* sidewalks.
- Shuttle buses can be implemented not only between bus stops and shopping center entrances but also from between different shopping centers.
- There is a tremendous need to have a computer-aided procedure and method by which travel time and number of transfers can be calculated for a trip from a random origin to a random destination in an urban area. With such a procedure, by generating a very large number of trips between residential areas and shopping centers, travel time and transfers can be computed. This could be based on the input of published bus schedules and street map and zoning data in computerized form such as in GIS databases.
- More effort should be made by agencies to publicize to the general public the extent and attributes of "choice" riders using the bus. This would encourage more choice riders to use the bus service.
- More emphasis should be placed on starting pilot projects to use shuttle buses from homes to bus stops and from bus stops to malls. Shuttle buses could also be used in pilot projects between a series of shopping centers.

- Further research is needed to examine whether patterns of ownership lead to some shopping centers being more accessible to bus patrons than others.

About the Author

SALAMEH A. NSOUR is an Assistant Professor in the Department of Civil Engineering at Santa Clara University in Santa Clara, California.

A Comparison of Pattern Recognition and Probabilistic Techniques for Capital Asset Deterioration

Matthew G. Karlaftis
Greek Air-Force Academy

Abstract

Capital asset management is a critical component of the operation of transit systems. In particular, much interest has been generated lately regarding the development of rolling stock deterioration models that can predict the future condition of a fleet from the corresponding deterioration curves. Based on a rolling stock inspection data set from Athens, Greece, this paper presents the development of both an ordered probit model and a predictive discriminant function that can be invaluable tools in predicting rolling stock deterioration. This combination of models provides a way in which we can get both aggregate (system level) projections on future bus conditions and disaggregate (individual bus level) projections. Both of the methodologies used recognize the ordinal nature of condition ratings and link deterioration to a set of relevant explanatory variables such as bus age, mileage, and size. The results can be easily used in a number of practical situations, such as capital asset life-cycle cost analysis, optimal timing for bus replacement, and examination of the effect of different operational strategies on bus deterioration.

Introduction

Capital asset management issues in the transit industry have attracted considerable research interest because of their wide variety of applications. Individual transit systems, for example, may be interested in identifying those factors that influence the deterioration of their capital assets (rolling stock and fixed facilities) to forecast the future condition of their fleet (possibly to examine the effectiveness of the current maintenance procedures) and make better investment decisions. State Departments of Transportation (DOTs), on the other hand, may wish to identify the present condition of capital assets (especially rolling stock), as well as forecast the percentage distribution of the condition of assets in the future at an aggregate (statewide) level. This information is essential, both for prudent capital funding requests and the completion of an effective Public Transit Management System (PTMS). Traditionally, these problems have been addressed in fairly simplistic and theoretically questionable frameworks. These models may not depict accurately the qualitative and quantitative relationships between capital stock deterioration and the various independent variables.

Capital asset condition is most often represented by inspection ratings (FTA 1994). Ratings are discrete ordinal measurements; that is, numbers assigned do not indicate distances between ratings, but only a relative ordering. For example, bus condition can be described on a scale of 0 to 4, where 4 stands for excellent condition, and 0 stands for bad condition. These discrete ratings are used instead of continuous indices, primarily for reducing the computational complexity of the Maintenance and Rehabilitation decisionmaking process. Unfortunately, deterioration models based on these discrete ratings are more complex to develop. Using ordinary regression analysis to forecast future condition (Galbraith 1996) does not recognize the discrete nature of condition ratings (the dependent variable is *not* continuous), and the assumption of zero mean and constant variance are not met. The purely stochastic (curve-fitting) method for predicting deterioration also suffers from the weakness that it does not link deterioration with any explanatory variables, such as age of bus, mileage, etc.

The increasing interest in transit capital asset management was promoted by the federal government with the requirement for a PTMS with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. This legislation required that the states implement a PTMS as ". . . a systematic process for providing relevant parties with the information needed to make informed decisions regarding their transit assets. . . ." Even though the PTMS is not a federal requirement as of 1996, states are encouraged to pursue its development. Several states (Michigan, Minnesota, California, and Indiana) and individual transit systems (New Jersey) continue to work on the development of statewide and individual PTMSs, suggesting the need for improvement of existing empirical models for rolling stock deterioration.

This paper focuses on the development of deterioration models that can be used for condition forecasting at both the aggregate and disaggregate levels. While the methodologies that we develop are applied to a rolling stock (bus) condition data base from Athens, Greece, the same methodologies easily can be used to develop deterioration models for other capital assets such as service vehicles, fixed maintenance facilities, etc. The remainder of this paper is organized as follows. In the next section, some of the necessary background for this work is provided. Then, the data, the methodology, and the estimated models used in the study are presented. Concluding remarks are presented in the final section of the paper.

Background

As previously mentioned, much of the early work in the empirical analysis of rolling stock deterioration data was done with the use of multiple linear regression. These models suffer from several methodological limitations and practical inconsistencies. To overcome these limitations, some authors developed a variety of different models that are reasonable descriptors of the bus deterioration process.

Ludwig (1997) describes the development of a deterioration model for the New Jersey Transit PTMS (individual transit system deterioration model). This model predicts deterioration rates as a function of the median years to transition from one condition state to the next (for example, the median time it takes for a bus to deteriorate from condition rating 4 to condition rating 3 is two years). This model, while an improvement over previously-used models, in that it recognizes the discrete nature of the dependent variable, links deterioration rates to median years to drop condition *only* and does not account for any other variables of interest, such as mileage and size of bus (buses of different size might have different deterioration rates). Further, this model does not allow for the possibility of keeping a bus for more that 12 years, performing a major engine overhaul, or altering maintenance practices.

Karlaftis and Sinha (1997), using a rolling stock inspection data set from Indiana, developed an ordered probit methodology for projecting future rolling stock condition. This methodology recognizes that rolling stock condition ratings are ordinal numbers. Further, and contrary to most other methods of rolling stock condition prediction, this method links deterioration to a set of explanatory variables (age, mileage, bus size, maintenance practices, and climatic region of the transit system). Their methodology provides intuitively appealing and theoretically sound models that are useful tools in projecting future rolling stock condition at the aggregate (statewide) level. Nevertheless, while this methodology easily lends itself to aggregate forecasting (at the state or individual system level), it is not easily amenable to "what-if" analyses for individual buses. That is, we cannot easily examine what the effects of changing various strategies (maintenance, driving, etc.) are on *individual* buses. This information could be very useful in cases where systems are considering purchasing new vehicles or are attempting to determine alternate maintenance and driving strategies to reduce a bus's deterioration.

In this paper, a discriminant (classification) function is developed for bus deterioration prediction using a data set from the Athens, Greece, Public Transportation Corporation (OASA). This model has the advantage of being easy to use and can straightforwardly provide future condition ratings for individual buses. The model and its predictions are also compared to the ordered probit model proposed by Karlaftis and Sinha (1997).

The Data

Athens, the capital of Greece is one of the most heavily congested cities in Europe. Its population of approximately three million accounts for about 30 percent of the entire population of Greece. In 1996, there were approximately 1.25 million registered vehicles, 950,000 of which were private automobiles. OASA, the sole provider of public transportation services (government owned and operated), plays an integral role in the mobility of citizens and in the effort to relieve congestion and improve air quality in Athens. In Table 1, some of the basic operating characteristics for OASA are presented.

Table 1
Characteristics of the OASA Bus Transit System (1994)

Total Fleet Size	1,782
Vehicles in Daily Operation	1,683
Annual Vehicle-Kilometers	92,332,000
Annual Passengers	431,853,000
Routes Executed Daily	13,932
Routes per Bus in One Shift	4.9

The data used in this study were obtained from the OASA Inventory data base and includes the entire 1,782 buses used in all the routes served (by OASA) in Athens. The data set contains inspection records for the year 1996, using the condition rating system described in Table 2. The condition rating used was pro-

Table 2
Rolling Stock Condition Ratings

Condition	*Description*
0 = Bad	In sufficiently poor condition that continued use presents potential problems
1 = Poor	Requires frequent major repairs
2 = Fair	Requires frequent minor repairs or infrequent major repairs
3 = Good	Requires only nominal minor repairs
4 = Excellent	Brand new, no major problems exist

posed by FTA (1994) and has since been extensively used in the development of bus deterioration models (Galbraith 1996, Ludwig 1997, Karlaftis and Sinha 1997).

Examining the age of the existing vehicles yields the histogram of Figure 1. It is very interesting to note that approximately 35 percent of the buses in Athens are between 3 and 5 years old, while the remainder are between 11 and 17 years of age. It does appear that there were no significant bus purchases between 1986 and 1992, and this presents a potential problem because the existing fleet will soon be too old to efficiently serve the population of Athens. Indicative of this problem is Table 3, which shows the condition rating of the existing OASA bus fleet. It is important to note that approximately 50 percent of the fleet is in either bad or poor condition. As the literature suggests (FTA 1994), when bus ratings drop to 0 ("bad"), buses are not only unable to efficiently serve the population, but, most importantly, are unsafe and should be retired from service. Frequently, when the condition rating drops to 1 ("poor"), a strong case can be made for the purchase of new buses; the expense associated with the purchase can be offset by the savings in the high maintenance expenses associated with buses in this condition.

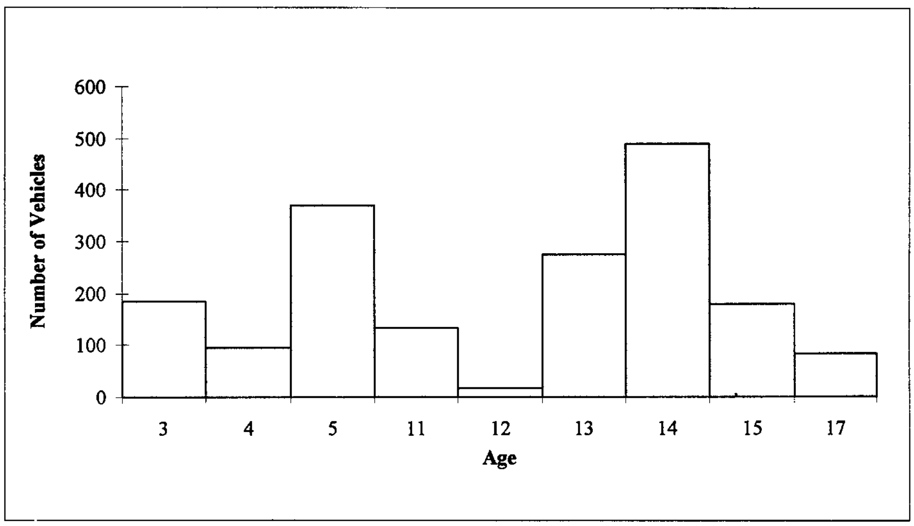


Figure 1. Age of the existing OASA bus fleet.

To evaluate the need and timing of bus replacement, a deterioration model was developed that allows OASA to predict the condition of both its entire fleet and that of individual buses.

Table 3
Percentage of OASA Buses in Each Condition Rating

Condition	*% of Buses*
0	4.76
1	41.38
2	18.28
3	20.20
4	15.38

The Methodology

The Ordered Probit Methodology

The first model was developed primarily for aggregate forecasting and is similar to the one proposed by Karlaftis and Sinha (1997). This model is an extension of the simple and widely used binary probit model. The ordered probit model considered here falls into the category of discrete ordered choice models. That is, this model is an extension of the probit model in which there is an ordering of the categories associated with the dependent variable (the dependent variable has a natural interpretation as an increasing integer). The ordered probit model assumes that there are cutoff points, μ's, which define the relationship between the observed and unobserved dependent variable.[2] Specifically, the ordered probit model is built around a linear-in-the-parameters latent regression, linking the latent deterioration y^* and a set of observable exogenous variables as follows:

$$y^* = \mathbf{b}' \mathbf{X}_i + \varepsilon_i \tag{1}$$

where,

$\mathbf{b}$ = a vector of parameters to be estimated

$\mathbf{X}_i$ = a vector of exogenous variables for bus i

ε_i = random error term

The above relationship cannot be directly estimated, since y^* is unobservable. What is *actually observed* is the condition ratings. These ratings, (i.e., the indicators of y^*), are used in the estimation of the deterioration model. As a result, what is actually observed in the case of bus deterioration is:

$$\begin{aligned} y &= 0 \text{ if } \quad\quad\; y^* \leq \mu_0 , \\ y &= 1 \text{ if } \mu_0 < y^* \leq \mu_1 , \\ y &= 2 \text{ if } \mu_1 < y^* \leq \mu_2 , \\ y &= 3 \text{ if } \mu_2 < y^* \leq \mu_3 , \\ y &= 4 \text{ if } \mu_3 < y^* \end{aligned}$$

The μ's are unknown parameters that are estimated along with **b**. The respondents to the condition survey have their own intensity of feelings regarding the specific condition of a bus, which depends on certain measurable factors, $\mathbf{X}_i$ (such as mileage, age, etc.), and certain unobservable factors, ε_i. Theoretically, respondents could assign their own y^* if they were "allowed" to do so. Given the five possible condition ratings, they choose the rating that most closely represents their own assessment of the bus condition. The parameters of the equation, as well as the thresholds and the asymptotic standard errors, are estimated simultaneously using maximum likelihood estimation.

The Discriminant Analysis Methodology

Predictive discriminant analysis (commonly referred to as classification analysis in the physical sciences or as pattern recognition in engineering and computer science) is a multivariate technique concerned with assigning objects (observations) to previously defined groups. The basic purpose of a predictive discriminant analysis (PDA) can be described as follows:[2] Suppose there are samples from π_g populations (condition ratings) of size n_g, $g = 1, 2, \ldots, k$, with X measures (independent variables) on each of the N ($N = \sum n_g$) units. Using this N x X data matrix, we want to determine from which of the π_g populations an ($N + 1$)st unit is most likely to have been randomly sampled. To accomplish this task, the *maximum likelihood principle* is used: Assign a unit to the population in which its observation vector has the greatest likelihood of occurrence. More formally, this can be stated as:

$$\hat{d}_g(i) = \max\{\hat{d}_1(i), \hat{d}_2(i), \ldots, \hat{d}_k(i)\}, i = 1, 2, \ldots, N, g = 1, 2, \ldots, k \quad (2)$$

The functional form of the discriminant function d_g depends on two factors:

1) whether the populations are normally distributed, and
2) whether the populations have equal or unequal covariance matrices.

With normal populations and equal covariance matrices, the discriminant function (DF) is linear. With normal populations but unequal covariance matrices, the discriminant function is quadratic. Finally, with non-normal populations, the discriminant function is non-linear and is estimated using nonparametric procedures (such as *kernel* estimation) (Huberty 1994). Selecting among these functional forms can be done by testing for normality of the populations and for equality of the covariance matrices.

Model Estimation, Validation, and Forecasting

Model Estimation

The estimation results for the ordered probit model using the OASA data set are presented in Table 4. The coefficients for the model have the expected signs: older buses, as well as buses with higher mileage (expressed as 100,000 kms), are associated with lower condition ratings. Further, larger buses (higher capacity) are associated with lower condition ratings. This result seems to suggest that, in the case of OASA, either larger buses demonstrate a higher tolerance to the normal "wear-and-tear" of traffic, or that better care is taken of larger buses. It is worth mentioning that this last result (larger buses are associated with higher condition ratings) was similar to the result reported by Karlaftis and Sinha (1997).

The t-statistics for all the explanatory variables are highly significant, suggesting that all these variables are good descriptors of the bus deterioration process. The three additional parameters appearing in Table 4 (thresh 1, thresh 2, thresh 3) are the thresholds that can be statistically identified. There are four thresholds associated with five condition ratings, but the presence of a constant term in the specification of the model does not allow for the identification of one of the parameters. As such, the software used for the estimation of this model (LIMDEP7) normalizes the first threshold $\mu_0 = 0$. This normalization does not affect the relative values of the parameters and is done solely for estimation purposes (Greene 1990).

Table 4
Estimation Results for the Estimated Ordered Probit Model

Variable Name	*Ordered Probit Coefficient Estimates*
Constant	12.59
	(37.77)
Age (in years)	-0.78
	(-21.98)
Mileage (105 kms)	-1.22
	(-14.07)
Bus Capacity	0.007
	(4.28)
thresh 1	2.07
	(35.14)
thresh 2	4.69
	(37.51)
thresh 3	9.62
	(42.82)
Summary Statistics	
# of observations	1782
L(0)	-3959.21
L(β)	-1049.05
Rho-squared	0.73

To estimate the second model, the DF, the normality of the populations, as well as their covariance matrices, should be checked. Investigating multivariate normality is not as straightforward as assessing univariate normality. It is very difficult to construct a test for overall test of joint normality in more than two dimensions because of the large number of things that can go wrong (Johnson and Wichern 1992). One thing that can be done is to check for the normality of each variable distribution.[3] Using the SAS software (PROC UNIVARIATE and normal probability plots), the null hypothesis of univariate normality could not be rejected for any of the variables. Having satisfied multiple univariate normality, this investigation proceeds as though multivariate normality conditions are met. The second condition, that of equal population covariance matrices, can be examined straightforwardly since statistics are available that test this condition explicitly. The approach typically used tests the multivariate hypothesis $\sum_1 = \sum_2 = \ldots \sum_k$ (a generalization of the univariate hypothesis $\sigma_1^2 = \sigma_2^2 = \ldots \sigma_k^2$ using an approximate chi-squared (Barlett) statistic (Huberty 1994). Using SAS DISCRIM, the reported P value of the chi-squared statistic is 0.34, suggesting that the null hypothesis of covariance homogeneity cannot be rejected.

With normal populations and equal covariance matrices, a Linear Discriminant Function (LDF) is employed. As Lachenbruch (1975), Titterington (1981), and Gilbert (1968) suggested, LDF perform well on ordered discrete categories. The coefficients of the LDF that are estimated appear in Table 5. Notice that for each condition rating (0-4), there is a different LDF. Using these LDFs and the maximum likelihood rule, the observations to the various condition ratings can be classified.

Table 5
Linear Discriminant Function

	Condition Rating				
Variable	*0*	*1*	*2*	*3*	*4*
Constant	-333.55	-282.34	-247.51	-189.72	-40.88
Age (years)	13.29	12.09	11.88	12.52	13.18
Mileage (10^5 kms)	42.43	38.42	35.35	26.27	-12.41
Capacity	0.46	0.51	0.44	0.43	0.30

Model Validation

In the case of the ordered probit model, its goodness-of-fit can be assessed by employing the ρ^2 measure. Commonly defined as $1-(L(\beta) / L(0))$, it measures the fraction of the original log likelihood value explained by the model. In non-linear models, ρ^2 is not as intuitive as R^2 is in regression, but it still gives an indication of the goodness-of-fit of the model. The 0.73 value obtained for this measure is considered as very good in the non-linear model case. To further examine the goodness-of-fit of the ordered probit model, Table 6 presents the number of predicted vs. actual buses in each condition rating. The model appears to be giving good predictions for most condition ratings. An exception might be condition rating 2, where the model predicts correctly 63.3 percent of the buses, but predicts 102 in lower conditions, and 33 in higher. Overall, the model predicts correctly the current condition rating of 88.43 percent of the buses, a number which is quite high.

Table 6
Frequencies of Actual and Predicted Outcomes–Probit Model

Actual	*Predicted (number of buses)*						
Condition Rating	*No. of Buses*	*Condition Rating* 0	1	2	3	4	*% Correctly Predicted*
0	194	194					100.00
1	425	10	394	21			92.70
2	368	3	99	233	33		63.30
3	156			40	116		74.35
4	639					639	100.00
Total:	1782					Overall:	88.43

In the case of the LDF, there is no single measure of model goodness-of-fit (such as ρ^2). To validate this model, the *holdout procedure* (Rencher 1995) was used. In this procedure, all but one observation is used to compute the classification function, and this function is subsequently used to classify the omitted observation. This process is repeated until each observation is classified by a function based on the other observations. This method was used to estimate the correct prediction rates, while the actual LCF presented in Table 5 is based on the entire set of observations. Table 7 indicates that the model yields predictions that are similar to the ones obtained from the probit model. The overall correct prediction rate of 87.03 percent is again high.[4] It is worth noting that a quadratic classification function was estimated, thus relaxing the covariance homogeneity requirement of the linear function. There was *no* improvement in the overall correct predictions when this method was used.

Table 7
Frequencies of Actual and Predicted Outcomes—Linear Discriminant Function

Actual		*Predicted (number of buses)*					
Condition Rating	*No. of Buses*	*Condition Rating* 0	1	2	3	4	*% Correctly Predicted*
0	194	194					100.00
1	425	28	371	26			87.29
2	368		108	225	30		61.10
3	156			34	122		78.20
4	639					639	100.00
Total:	1782					Overall:	87.03

Forecasting

Commonly, ordered probit models are estimated in the literature, but there is little effort in interpreting the estimated coefficients. To obtain a meaningful insight into the magnitude of the effects of each independent variable, the first derivative of the likelihood function (marginal effects) is needed. The marginal effects (Table 8) show the change in the probability of a bus being in a condition rating due to a one unit increase in some exogenous variable. For example, each additional 10^5 kms in the life of an OASA bus decreases the probability that it will be in condition rating 4 by 0.0944 and in condition rating 3 by 0.1138. On the other hand, it increases the probability that it will be in condition rating 2, 1, and 0 by 0.1072, 0.086, and 0.079, respectively. Based on these marginal effects and the estimated probabilities for each condition rating, the distribution of buses at different condition ratings as a function of bus age for OASA was computed (Figure 2).

Table 8
Marginal Effects for Ordered Probit Model

Variable	*0*	*1*	*Condition Rating* *2*	*3*	*4*
Age	0.079	0.086	0.1072	-0.1138	-0.0944
Capacity	0.007	0.001	-0.0009	-0.0013	-0.0011
Mileage	0.092	0.0910	0.1001	-0.1779	-0.1189

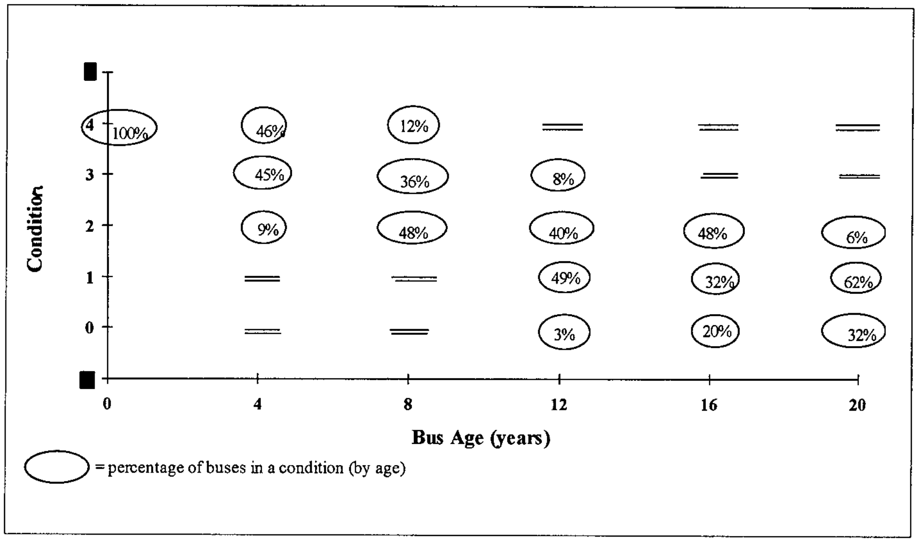


Figure 2. Forecast of the percentage of buses at different condition ratings vs. bus age for OASA

While the ordered probit model and the associated marginal effects can provide good aggregate forecasts of the condition of the entire bus fleet at a point in time, it is very difficult to examine the condition rating of an individual bus. Further, Figure 2 assumes that the other variables (kms and capacity) are at their *mean* levels. A transit system manager could be interested in the following scenario: Can the life of a given bus be prolonged (and by how much) if it is decided to restrict its daily circulation by a certain percentage? This is where the flexibility of the LDF lies. A three-year-old, 40-person bus (seating room) with 95,000 kms is correctly classified as being in condition 4.[5] The same bus after 15 years in service will be in condition 0 if it has been driven for 910,000 kms. If the same bus is driven more prudently (750,000 kms), it will be in condition rating 2. This type of analysis is very difficult to do using the ordered probit model or any other of the models that have been used to forecast capital asset deterioration. Using this type of process, a large number of "what-if" scenarios can be examined regarding the condition of individual buses under different driving strategies. Hopefully, at a later stage of the development of similar data bases, an explicit measure of the maintenance procedures used on a bus can be incorporated to evaluate the effects of alternate strategies on future condition ratings.

Conclusions

In this study, two models for examining capital asset deterioration in the transit industry were developed. These models were estimated based on a bus condition data set from Athens, Greece. The first model developed (ordered probit) allows the identification of factors that affect deterioration, as well as the quantification of the magnitude of these (marginal) effects. This way, an understanding of the relative importance of the different explanatory variables on bus condition can be gained. The second model (LDF) provides an easy and rather accurate way in which different mileage (and later on maintenance) scenarios on individual bus deterioration can be examined.

This combination of models provides a way in which to get both aggregate (system level) projections on future bus conditions and disaggregate (individual bus level) projections. Both methodologies used recognize the ordinal nature of condition ratings and link deterioration to a set of relevant explanatory variables such as bus age, mileage, and size. The results can be used easily in a number of practical situations. First, these results can be used to perform bus life-cycle cost analysis, determine optimal timing for bus replacement, and examine the effect of different operational strategies on bus deterioration. Finally, it is worth noting that both modeling frameworks, while fairly sophisticated in their theoretical development, are readily available in a large number of commercial computer software packages.

Endnotes

[1] In this section, only the essential parts of the ordered probit formulation that might be of interest to the reader are presented. Readers interested in the details of the formulation are encouraged to refer to Greene (1993) for an in-depth treatment or Karlaftis and Sinha (1997) for a presentation of the model in the context of rolling stock deterioration.

[2] Here, the very essential parts of discriminant analysis are again presented. For a more thorough analysis, refer to Huberty (1994).

[3] This is a necessary but not sufficient test for multivariate normality. In general, it is recognized that marginal univariate normality is not sufficient for joint normality. Nevertheless, as Stevens (1992) notes, for most practical work one-dimension investigations of normality are ordinarily sufficient. Further, data sets that are normal in lower dimensional representations but nonnormal in higher dimensions are very infrequent in practice (Johnson and Wichern 1992).

[4] In the standard PDF literature, the overall correct predictions are referred to as the "apparent correct classification rate." Frequently, authors use the associated "apparent error rate" (AER), which is 1-0.8703 = 0.1297. This AER is considered as very good in the standard PDF literature (Johnson and Wichern 1992).

[5] Classifying this bus in a condition rating using the LDF is very simple. Use the coefficients of Table 5 to obtain the discriminant function score. In this case: $\hat{d}_0(i) = -234.9$, $\hat{d}_1(i) = -189.1$, $\hat{d}_2(i) = -160.6$, $\hat{d}_3(i) = -110$, $\hat{d}_4(i) = -1.12$. Following the maximum likelihood rule (Eq. (2), this bus can be classified in condition rating 4.

Acknowledgment

This research was part of a project for the development of a bus deterioration and forecasting tool for OASA. The author is grateful to the President and staff of OASA for providing the bus condition data base used in this study.

References

Federal Transit Administration. 1994. *Rail Modernization Study*, U.S. Department of Transportation, Washington, D.C.

Galbraith, S. 1996. *Development of a Public Transportation Management System in Massachusetts*, unpublished Master's Thesis, Department of Civil and Environmental Engineering, University of Massachusetts, Amherst.

Gilbert, E. S. 1968. On Discrimination Using Qualitative Variables, *Journal of the American Statistical Association* 63: 1399-1412.

Greene, W. H. 1990. *Econometric Analysis*. New York: MacMillan Publishing Company.

Johnson, R. A., and Wichern, D. W. 1992. *Applied Multivariate Statistical Analysis*. Englewood Cliffs, N.J.: Prentice Hall.

Huberty, C. J. 1994. *Applied Discriminant Analysis*. New York: John Wiley and Sons.

Karlaftis, M. G., and Sinha, K. C. 1997. A Modeling Approach for Transit Rolling Stock Deterioration Prediction, *ASCE Journal of Transportation Engineering*, Vol. 123, No. 3: 223-228.

Lachenbruch, P. A. 1975. Discriminant Analysis, *Biometrics* 35: 69-85.

LIMDEP7. 1995. *User's Manual*. Bellport, NY: Econometric Software Inc.

Lynch, J., Karlaftis, M. G., Sinha, K. C., and Fricker J. D. 1997. The Indiana Public Transportation Management System, Presented in the 76th TRB meeting, Washington, D.C.

Ludwig, A. 1997. Systems Planning for Capital Asset Management: A Case Study of the New Jersey Public Transportation Facilities and Equipment Management System (PTMS), Presented in the 76th TRB meeting, Washington, D.C.

Madanat, S. M., and Wan Ibrahim, W. H. 1995. Estimation of Infrastructure Transition Probabilities from Condition Rating Data, *Journal of Infrastructure Systems*, Vol. 1, No.2.

Rencher, A. C. 1995. *Methods of Multivariate Analysis*. New York: John Wiley and Sons.

Titterington, D. M., Murray, L. S., Speigelhater, D. J., Skene, A. M., Habbema, J. D. F., and Gelpke, D. J. 1981. Comparison of Discrimination Techniques Applied to a Complex Data Set of Head Injured Patients, *Journal of the Royal Statistical Society, Series A*, 144, 145-175.

Stevens, J. P. 1992. *Applied Multivariate Analysis for the Social Sciences.* Hillsdale, NJ: Lawrence Erlbaum.

About the Author

Matthew G. Karlaftis is in the Department of Engineering in the Greek Air-Force Academy. He received his Ph.D. and was a visiting Assistant Professor in the Department of Transportation and Urban Engineering in the School of Civil Engineering at Purdue University in Indiana. His research interests include transportation economics, statistics, air transportation, and ITS.

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161 (703) 605-6000